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OOGENESIS IN VAUCHERIA.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXI.

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(WITH PLATES VI AND VII)

THERE have been published two accounts of the development of the oogonium of Vaucheria, attempting to explain in fundamentally different ways the final uninucleate condition of the structure at the maturity of the egg. All authors have found the young oogonium multinucleate, and the problem has concerned the history of these nuclei as the egg developed and the oospore matured. BEHRENS ('90), in partial agreement with SCHMITZ's opinion that the material discharged from the opening of the oogonium represented a polar body, believed that the final single nucleus of the egg resulted from the fusion of numerous nuclei in the oogonium. KLEBAHN ('92, p. 237), in criticism of the results of SCHMITZ and BEHRENS, held that the egg and oospore were multinucleate. OLTMANNS ('95) came to very different conclusions. He described the gradual withdrawal of all the numerous nuclei found in the young oogonium from that structure into the main filament, with the exception of one which was left to become the nucleus of the egg.

The view of BEHRENS was in general similar to those of HUMPHREY and HARTOG for Saprolegnia, since the latter writers believed that the numerical reduction of the nuclei in this form was the result of successive nuclear fusions. The explanation of OLTMANNS has no parallel in any process of oogenesis known to the writer. Neither of these accounts seems to be correct, and the processes of oogenesis

in Vaucheria are along very different lines, namely those of nuclear degeneration, which are in sympathy in all essentials with the events now known for gametogenesis in Saprolegnia (DAVIS '03), several members of the Peronosporales, and certain Ascomycetes.

These facts give a high degree of interest to Vaucheria, which becomes the greater in view of the position which this form takes in the phylogenetic systems of many authors as representing a possible point of origin of the Phycomycetes. This subject will be considered, with its bearings upon the writer's theory of the origin and evolution of the coenogamete, at the end of the paper, under the head of "Theoretical Considerations."

The material, identified as *Vaucheria geminata racemosa*, was collected at Chicago, the younger oogonia being abundant late in March and older stages a week or so later. Of the killing fluids employed, chromacetic acid after the formula of FLEMMING proved to be much the most satisfactory (1 per cent. chromic acid 25^{cc}, 1 per cent. acetic acid 10^{cc}, and water 65^{cc}). This formula is $\frac{1}{4}$ per cent. chromic acid and $\frac{1}{10}$ per cent. acetic acid. Chromic acid in excess of $\frac{1}{2}$ per cent. produced serious shrinkage. The weaker solution of iridium chlorid and acetic acid (Eisen) also gave fair results ($\frac{1}{2}$ per cent. iridium chlorid and 1 per cent. acetic acid). The cytoplasmic structure and plastids were perhaps better preserved in the latter fluid, but the nuclei did not stain so readily. All mixtures with osmic acid were objectionable, because the protoplasm of Vaucheria is filled with oils and fats which became so seriously blackened that they could not be thoroughly bleached. Chromic acid takes out much of these troublesome substances, or at least leaves the material so that it can be readily cleared. Paraffin sections were cut $5\,\mu$ thick and stained with safranin and gentian violet. The nuclei are so minute as to require the best of lenses, and the Zeiss apochromatic objective 1.5^{mm} with the compensating oculars was used entirely.

The oogonia are somewhat variable in number (2–6) and are arranged in a whorl near the end of short lateral branches just below the terminal antheridium. They commence their development as small protuberances which from the beginning are multinucleate (*fig. 1*). As growth proceeds the process enlarges and takes a globular form on the end of a short stalk (*figs. 2–4*). It is evident that

the enlargement is accompanied by a stretching of the cell wall, which is always much thinner about the young oogonium than around the stalk and vegetative filament, a fact which is clearly shown in *figs. 4, 5, 6,* and *7*. The growth of the oogonium results from the accumulation of large amounts of protoplasm with numerous nuclei and chloroplasts, together with the formation of vacuoles which flow together, so that finally the protoplasm lies peripherally around a central space crossed by a few delicate strands and films of protoplasm.

The number of nuclei is variable, but always large; the range is probably from about 20 to 50. These nuclei are carried into the developing oogonium by the accumulation of protoplasm. They lie very close together at the tip of the young structure (*fig. 1*), but become scattered as growth proceeds, agreeing in this respect with the conditions found in all the growing points of Vaucheria. I have seen no indication of nuclear division in the oogonium, and am positive that it does not occur in stages as old or older than those shown in *figs. 2* and *3*. It is quite probable that mitotic figures are present in the vegetative branch before the development of the oogonia, but I have never seen the spindles. The nuclei are so very small and the plastids so numerous that studies of nuclear division in Vaucheria will be very difficult. It is important to note that there are no mitoses during the growth of the oogonium and none after its separation by the cross wall from the parent filament. In these respects oogenesis in Vaucheria is somewhat different from the processes as known in Saprolegnia and the Peronosporales, where there seem to be always one or two general mitoses after the oogonium is formed. The absence of nuclear divisions during oogenesis in Vaucheria presents serious difficulties for the theories of some authors that such mitoses indicate reduction phenomena in those fungi where they have been most studied. These speculations have been recently criticised by the writer (DAVIS '03, pp. 339–342) and the subject will be further considered later in this paper.

We will now describe he development of the cross wall by which the oogonium is separated from the parent filament. It appears when the oogonium is about two-thirds its mature size. The wall is laid down between two plasma membranes, as was shown by HARPER ('99) for the

formation of sporangia in Pilobolus and Sporodinia, and by DEAN SWINGLE ('03) in Rhizopus and Phycomyces. The plasma membranes are formed chiefly along the surfaces of flattened vacuoles. I have seen no evidence of furrows cutting inward from the surface as takes place in Pilobolus and Rhizopus, but such structures would not be seen easily in Vaucheria because the stalk is rather narrow. *Fig. 4* illustrates an arrangement of vacuoles at the base of an oogonium which would probably have determined the position of the cross wall, and *fig. 5* shows a more advanced condition when the plasma membranes have definitely separated from one another. The stages shown in *figs. 6–8* are all somewhat older than that of *fig. 5*, and there is evidence in all of them that the wall has began to form as a delicate film visible at certain points between the two plasma membranes.

The oogonium at the time of the formation of the cross wall is multinucleate. There is no evidence in my material of the withdrawal of nuclei from this structure, as described by OLTMANNS, before the wall is laid down, and my preparations indicate that the oogonium contains as many nuclei immediately after the formation of the wall as before. These conditions are shown in *figs. 5–7*. The number of nuclei is always large, but is variable, ranging from 20 to 50. They may be readily demonstrated at this period when properly stained, but are very difficult to trace from this stage of development onward because of the remarkable and rapid nuclear degeneration which sets in at this time. This interesting phenomenon is apparently exactly the same as that which takes place at closely corresponding periods of oogenesis in Saprolegnia and in several of the Peronosporales.

The degeneration of the nuclei really begins a little before the oogonium is separated from its parent filament. At that time the nuclei in the oogonium do not stain as strongly as those in the antheridium and in neighboring portions of the vegetative filament. The nuclear membrane is less distinct and there is very little substance in the nucleus except the large nucleolus. *Fig. 9* presents a series of nuclei from the same section of which *fig. 7* is a single oogonium. In *fig. 9*, *a* is a nucleus from the antheridium, *b* from a region of the branch slightly below the antheridium, *c* from near the oogonium,

and *d* from within an oogonium. It will be seen that *a*, *b*, and *c* are nuclei which, although small (magnified 2,000 diameters), present the structure of the nuclei of higher plants; that is, each has a nucleolus lying among granules of a chromatic nature and linin. In *c* these structures are less conspicuous than in *b*, while *d* shows unmistakable signs of degeneration, for its nuclear membrane appears very faint and there is scarcely any trace of chromatin or linin. The nucleolus, however, is generally large and stains deeply and is always the last structure in the nucleus to disappear. *Figs. 6* and *7* show degenerating nuclei in oogonia shortly after the formation of the cross wall.

It is very difficult to trace the degeneration and final dissolution of the numerous nuclei in the oogonia, because we are dealing with structures that become more and more difficult to stain and find. It becomes in the end impossible after the nuclear membrane disappears and the nucleolar material is scattered throughout the cytoplasm. These baffling conditions are identical with those in the oogonium of Saprolegnia which the author has recently described (DAVIS '03, p. 239).

The mature oogonia are finally uninucleate. There seems to be no doubt of this condition, and the factors governing the selection and survival of the fortunate nuclei are of interest. We know that the process in Saprolegnia (DAVIS '03, p. 239–243) is intimately connected with the presence of organized structures in the protoplasm, the coenocentra, which are probably the morphological expression of dynamic centers. I have not been able to find a coenocentrum in Vaucheria. It is possible that the plastids might obscure such a structure, but this is not likely unless it were very small. But there are conditions around the surviving nucleus in the oogonium which closely resemble those of the Saprolegniales and Peronosporales.

Before the formation of the cross wall the protoplasm in the oogonium is arranged quite irregularly. There is always the rather thick peripheral layer just inside the cell wall, but the interior region generally contains several irregular vacuoles which frequently open into one another. These conditions are partially shown in *figs. 3–5*, but of course they can be understood only by the examination of a number of consecutive sections.

After the formation of the cross wall, the arrangement of the cell contents becomes more regular. The oogonium increases rapidly in size, and the peripheral layer of protoplasm grows proportionally thinner. The strands and films of protoplasm that before crossed the oogonium irregularly become arranged so that there is a gradual accumulation of the protoplasm in the center of the cell, held in position by delicate strands which pass to the periphery, and the surviving nucleus always lies within this region. *Figs. 10–12* illustrate these conditions as they appear in thin sections (5 μ), but they cannot show the numerous radiating strands that hold the central mass in place. The degenerating nuclei lie chiefly in the peripheral layer of protoplasm, but some may always be found in the larger strands that enter the interior of the oogonium.

Although I have not been able to find any morphological evidence which would indicate that this accumulation of protoplasm is a dynamic center of the cell, there are good reasons for thinking that it really is such. The surviving nucleus of the oogonium is always found in this central mass surrounded by plastids and deeply staining granular protoplasm, which suggests material of a trophoplasmic nature. The peripheral protoplasm forms a thin layer under the cell wall in which one may find for a long time traces of the other nuclei that have degenerated. *Figs. 10* and *11* show some of these nuclei (*d*) so far reduced that there is nothing left but a deeply stained (with safranin) globule of nucleolar material apparently lying free in the protoplasm. No one would relate these structures to nuclei unless he had followed their history through the process of degeneration, for they are soon reduced almost beyond the point of recognition. But at this time the surviving nucleus (*fig. 10*) near the center of the oogonium increases rapidly in size until in the mature egg (*fig. 11*) it is three or four times as large as the original nuclei in young oogonia. The inference is plain that the central region of the oogonium is a much more favorable situation for nuclear growth and activities than at the periphery.

For this reason the author considers the dense central mass of protoplasm as comparable to the region of the egg in Saprolegnia and the Peronosporales which is dominated by the coenocentrum. It is apparently the region of the cell most favorable for nuclear

growth and activity, and as such is a dynamic center. There is a very close resemblance to certain of the Peronosporales (*e. g.*, Pythium) whose oogonia have merely an accumulation of dense protoplasm in place of the usual well-defined coenocentrum.

The growth of the surviving functional gamete nucleus presents some interesting features. There is a marked increase in the amount of chromatin which fills the interior with numerous small granules on a very delicate linin network. The nucleolus does not increase in size, so that it appears relatively much smaller in the older nucleus than in the younger (compare *fig. 11* with *figs. 3* and *4*). *Fig. 11* is of an oogonium almost at maturity, and *fig. 12* is after fertilization and shows two gamete nuclei fusing and also the remains of three sperms which were unable to enter the egg.

The final steps in the maturation of the egg, as has been frequently described, consist in the breaking down of a portion of the wall of the oogonium and the formation there of a pore through which the sperms enter. Much slime is developed, which partially exudes from the opening. Numerous sperms are attracted to the oogonium, and one may frequently find conditions such as are shown in *fig. 13*, where the slime at the opening is filled with sperms held in the mucilaginous matrix. It is possible that such conditions were interpreted by Schmitz as nuclear material thrown off from the egg as a polar body.

The union of the gamete nuclei takes place slowly. The male nucleus increases greatly in size, apparently being nourished in the dense central region of the egg, and the great increase in the amount of chromatin is as conspicuous here as in the female nucleus. Although the male nucleus is much smaller at first than the female, the two are approximately the same size before they begin to fuse (*fig. 14*), and both show essentially the same structure at that time. As fusion proceeds the two nuclei become indistinguishable (*fig. 12*).

The history of oogenesis in Vaucheria may then be briefly described as from a multinucleate gametangium, by a process of rapid and complete degeneration of all the nuclei except one, which is reserved with all of the protoplasm for a single uninucleate egg. In these respects Vaucheria offers certain important differences and yet some fundamental points of agreement with the conditions in the Saprolegniales and Peronosporales, which will now be considered.

THEORETICAL CONSIDERATIONS.

The essential agreement of the processes of oogenesis in Vaucheria with those of Saprolegnia and members of the Peronosporales is most striking. The oogonium in all of these forms so far known—Vaucheria, Saprolegnia, Pythium, Peronospora, Plasmopara, Sclerospora, Albugo, and Araiospora (KING '03)—is differentiated from the parent filament as a multinucleate cell. There may be one mitosis in the oogonium (Saprolegnia), or two as in certain of the Peronosporales, or there may not be any (Vaucheria), but finally extensive nuclear degeneration always begins. From among the weakened nuclei one or more are selected to preside over the eggs. The position of these surviving gamete nuclei in relation to favorable dynamic centers of the oogonium determines their selection and leads to extensive regenerative growth. In Saprolegnia and some of the Peronosporales (*i. e.*, Albugo, Peronospora, Plasmopara, Sclerospora) the dynamic centers are marked by the protoplasmic structures called coenocentra, which are apparently trophoplasmic in character, since they exert a chemotactic influence on the gamete nuclei near them and are obviously concerned with their later growth. Although there is no coenocentrum in Vaucheria, the surviving nucleus takes its position in a central mass of protoplasm which is evidently the most favorable situation in the oogonium for its growth, and as such is a dynamic center, although there is little morphological evidence of the condition.

The fact that there are no mitoses in the oogonium of Vaucheria is seriously against the view that they have relation to reduction phenomena when present in the oogonia of Saprolegnia and the Peronosporales. I have already expressed the conviction (DAVIS '03, pp. 339–342) that these mitoses in the oogonium have no such significance, because they are so variable in their appearance and because there is no positive evidence of such functions. ROSENBERG ('03) from studies on Plasmopara believes that a synapsis condition preceding the first of the two mitoses in the antheridium and oogonium of this form indicates reduction phenomena comparable to that in the tetrad division of the spore mother-cell of higher plants. The author has recently (BOT. GAZ. **36**: 154–155. 1903) criticised this view in several respects, which need not be repeated here, and the absence of mitoses

in Vaucheria offers further difficulties for such a theory. RUHLAND ('03) is also unwilling to follow ROSENBERG in his theory of reduction.

For these reasons the writer believes that the mitoses in the oogonia and antheridia of the Phycomycetes have no special significance, or are merely the remains of nuclear divisions that were formerly characteristic of simpler types of gametangia or perhaps the primitive sporangia that preceded these.

The simple processes of oogonesis in Vaucheria seem to prove conclusively that all of the nuclei in the oogonium are homologous and potentially gamete nuclei, and this supports HARTOG'S suggestion for Saprolegnia of many years ago. The author believes this to be equally true of the nuclei in the gametangia of the Saprolegniales and the Peronosporales. The mitoses in the last two groups have complicated the problem, but there seems now to be no special significance in these divisions, since they are not only variable in number, but may be entirely absent. Thus there are two mitoses in Albugo and Plasmopara, but only one in Saprolegnia, certain species of Peronospora, and Pythium, and they are entirely absent in the species of Vaucheria just described.

There are then excellent reasons for considering all of the potential and functional gamete nuclei in Vaucheria, Saprolegnia, and the Peronosporales as homologous, and there seems to be little doubt but that the oogonia of all these forms are related at least as gametangia through remote ancestors, if not as fully differentiated oogonia.

The problems then concern the exact relationships between the eggs of Vaucheria, Saprolegnia, and forms of the Peronosporales. Are these female gametes strictly speaking homologous, or have they been developed along somewhat different paths? An old view, and that probably held by most botanists, is one of strict homology, implying an intimate relationship between these fungi and Vaucheria. It is a problem of fundamental importance in all discussions of phylogeny in this region of the plant kingdom, and of special concern to those who make Vaucheria the starting point of a series of fungi beginning with the Peronosporales or the Saprolegniales and ending in the Mucorales.

From all points of view oogenesis in Vaucheria is simpler than in the Saprolegniales or Peronosporales. It conforms perfectly to well-

known principles of sexual evolution which the author has recently discussed (*Popular Science Monthly*, February 1903, p. 300). The process represents the final stage of nuclear reduction in a multinucleate oogonium, and indicates plainly that the ancestral gametangium produced numerous gametes which were undoubtedly motile, since the sperms of Vaucheria are biciliate and the Siphonales reproduce almost universally asexually by zoospores. It is difficult to follow exactly the steps through which the ancestors of Vaucheria passed in their evolution from isogamy, because it is the only heterogamous type in the order, and there are few connecting links with the prevailing simple conditions among the Siphonales. However, we have in Bryopsis a form whose gametes, although both motile, are of different sizes, those of the female being much larger and developed less numerously in the gametangium. This type exhibits the first step toward the condition of heterogamy, but we do not know exactly what would follow next. Probably the protoplasmic cleavage in the female gametangium would become gradually reduced and fewer gametes formed, until finally there would be no more cleavage, all of the protoplasm going into a single gamete, which when non-motile would become the solitary egg (Vaucheria). This concentration of protoplasm for a lessened number of gametes or for a single egg must be accompanied by nuclear degeneration *if the ancestral gametangium were multinucleate*. There are of course types of gametangia among the algae which are uninucleate from the beginning, and there cannot be any nuclear degeneration in these. But the multinucleate gametangium is not uncommon in certain groups, and is apparently universally present in the Siphonales.

It is possible that Sphaeroplea will be found to represent a stage in sexual evolution intermediate between Bryopsis and Vaucheria, without necessarily implying a relationship to these types. Klebahn ('99) and Golenkin ('99) have given us the most complete accounts of oogonesis in Sphaeroplea. Klebahn found the eggs of *S. annulina Braunii* to contain several nuclei (2–5), one of which became the functional female gamete nucleus; the others remained inactive and might be found in the ripe spore. It becomes an interesting question whether or not these would eventually degenerate. This form of Sphaeroplea may illustrate the beginning of a process by which

fewer eggs are developed than the number of gamete nuclei, but before a habit of nuclear degeneration has become fully established. It is altogether probable that the extra nuclei in the eggs of the var. *Braunii* do eventually break down.

Besides Sphaeroplea, it is very important that we know the processes of oogenesis in Monoblepharis, since this form has a structure with many points of resemblance to the algae on the one hand and the groups of Saprolegniales and Peronosporales on the other. LAGERHEIM ('00) states that a single large nucleus enters the developing oogonium to become the gamete nucleus of the egg. Such a history is not in sympathy with oogenesis in Vaucheria and the Peronosporales or Saprolegniales, nor is it in sympathy with his own description of spermatogenesis in Monoblepharis. The antheridium contains many nuclei, each of which enters into the development of a sperm as in Vaucheria. The author cannot but think that LAGERHEIM's account of oogenesis is incorrect, or else that the conditions here are very exceptional. It seems very probable that Monoblepharis and perhaps some of the forms in the Leptomitaceae are closely related to Vaucheria.

The problem of the relationship of the events of oogenesis in the Saprolegniales and Peronosporales to Vaucheria may be stated as follows. Have the conditions in these groups been developed directly from the relatively simple process illustrated by Vaucheria, or are there peculiarities in these two groups that would make necessary their derivation from more generalized types?

The Saprolegniales present conditions that superficially bear a very close resemblance to Sphaeroplea, *i. e.*, there are several eggs in the oogonium. But these eggs are differentiated around coenocentra which determine the survival of a limited number of nuclei, while the great majority break down. There are fundamental differences between these events and oogenesis in Sphaeroplea, unless later studies should establish nuclear degeneration in the latter type. It would not be difficult to conceive the development of several metabolic centers in a large gametangium of one of the Siphonales, and the survival of several nuclei to form as many eggs which would give a condition exactly like that of Saprolegnia. So the present investigation with the discovery of a multinucleate oogo-

nium in Vaucheria tends to bring the Saprolegniales into a somewhat close relationship to Vaucheria, not directly of course, but probably through more generalized types of the Siphonales now extinct.

The Peronosporales offer a more difficult problem than the Saprolegniales, yet there are fundamental features of oogonesis here in agreement with this group and with Vaucheria, namely a multinucleate oogonium and extensive nuclear degeneration. The advance of the process of oogenesis in the Peronosporales over that of Vaucheria lies in the differentiation of ooplasm and periplasm, the first being associated with a remarkably well-developed coenocentrum. The influence of this coenocentrum determines the survival of one or more nuclei in the ooplasm to give a uninucleate or multinucleate egg. The periplasm, containing numerous nuclei, becomes separated from the ooplasm, and although assisting in the deposition of the oospore wall its nuclei and cytoplasm finally become disorganized.

The processes of oogenesis in the Saprolegniales and Peronosporales seem higher than those of Vaucheria because of the remarkable activities of the coenocentra. But to derive the sexual organs of the first two groups from the last form, it would be necessary to postulate the suppression of two important activities in Vaucheria, namely, the development of motile sperms and the formation of pores in the gametangia for the entrance and exit of these structures. The suppression of the pore formation and consequent modification of the sexual cells, the establishment of several coenocentra in the Saprolegniales, and the specialization of a periplasm in the Peronosporales are peculiarities involving very important protoplasmic activities not represented in Vaucheria.

We have in the Saprolegniales and Peronosporales the interesting association of complex female organs developing eggs, with male organs that are much simpler. The antheridia in the first two groups are all mutinucleate and morphologically gametangia. In certain forms (*Albugo Bliti* and *A. Portulacae*) the antheridia are actually coenogametes as truly as those of the Mucorales, because large numbers of functional gamete nuclei are discharged into a multinucleate egg. Uninucleate gametes, probably motile in ancestral types, have been given up, and the antheridium, acting as a unit, follows the chemotactic tendencies of a male sexual cell in its fusion

with the female. All of these antheridia behave in the same manner whether there are one or many functional gamete nuclei. This condition must have been closely associated in its origin with the suppression of the habit of forming pores for the discharge of zoospores or motile gametes.

We do not know enough about the pore-forming activity in zoosporangia and gametangia to understand how readily it may be given up, and whether its presence or absence is of great morphological importance. The activity is absent in the gametangia of the Mucorales, Saprolegniales, and Peronosporales, but present in the sporangia of the Saprolegniales and most Peronosporales (conidia which produce zoospores), although lacking in some forms (Peronospora and certain species of Pythium) whose conidia germinate by a tube. The sporangia of the molds may have at one time developed zoospores, but there is at present no hint of such possible activities, except a general agreement in the processes of protoplasmic cleavage by furrows with spore formation in such zoosporangia as have been studied (Hydrodictyon, Saprolegia, etc.).

If the suppression of the pore-forming activity may take place readily after some slight change in life-habits, there would seem to be no great difficulty in relating the processes of oogenesis in Saprolegnia and the Peronosporales rather closely to Vaucheria or relatives of Vaucheria. But if pore-formation may be given up only under exceptional conditions and infrequently, then it becomes very questionable whether there can be a close relation to Vaucheria, and we must look to another line of ancestry for the Saprolegniales and Peronosporales. The author thinks the latter condition at least quite possible and deserving of further consideration.

Such an ancestry for the Saprolegniales and Peronosporales would naturally be sought through simpler conditions, somewhat like those illustrated in the Mucorales whose gametangia are coenogametes. It is scarcely conceivable that the molds are very closely related to the first two groups, but their coenogametes illustrate such well-defined sexual conditions that they naturally enter into the discussion. It is possible that groups with coenogametes like those of the molds might gradually differentiate such structures until they would finally become male and female sexual organs. The female

coenogamete would be larger and well supplied with food material, and might finally develop one or more eggs and thus become an oogonium; the male coenogamete in contrast would remain small or perhaps become further reduced and would be called an antheridium when it bore a sexual relation to an oogonium. Thus conditions like these of the Saprolegniales and Peronosporales might arise from coenogametes resembling those of the molds, and a condition of heterogamy result, which would closely resemble that of Vaucheria and yet have no genetic relation to the latter condition. The eggs of the Saprolegniales and Peronosporales in such an event would have an origin entirely independent of any other line of sexual evolution, and with the conspicuous peculiarity of coenocentra marking the position of dynamic centers during the process of oogenesis.

A question sure to be raised in this connection is the possibility of undifferentiated coenogametes of the mold type arising through the simplification or degeneration of organs like the antheridia and oogonia of the Saprolegniales and Peronosporales. Such a line of evolution would demand the suppression of some very highly differentiated cell processes, such as the extensive nuclear degeneration, the formation of coenocentra, and the differentiation of periplasm. There is no evidence of such tendencies among the forms in question, but, on the contrary, excellent reasons for believing that the direction of sexual evolution is toward greater and more precise protoplasmic complexity rather than simplification. The point is especially well illustrated in the series of species in the genus Albugo, where the line is clearly from the multinucleate egg and small coenocentrum of *A. Bliti* to the uninucleate egg and extraordinary large coenocentra of *A. candida* and *A. Lepigoni*. The author can see at present no probability of a line of sexual degeneration or simplification from higher forms toward the molds.

For these reasons we are driven to consider the possibility of an origin of the coenogametes of molds from gametangia that have not passed the stage of isogamy. I have previously (DAVIS '00, p. 308, and '03, p. 335) advanced the hypothesis that such coenogametes may have arisen from gametangia somewhat like those now found among the lower Siphonales and in Cladophora. These gametangia are generally terminal structures that discharge motile gametes.

But should organisms of this type (whether algae or fungi) be placed under conditions unfavorable for the formation of motile gametes, the gametangia themselves might be expected to act as coenocytic units, and obeying the chemotactic influences of sexual cells fuse with one another as coenogametes.

So the problems of phylogeny in this higher region of the Phycomycetes become greatly complicated through factors that concern the environment and life-habits of the forms in question. The absence of pores in structures that at one time evidently formed motile gametes presents great difficulties to the establishment of relationships between the Mucorales, Saprolegniales, Peronosporales, and Vaucheria. Yet, it may be that the suppression of this structure indicates little more than a change in life-habit from an aquatic to an aerial existience (Mucorales) or to a parasitic life (Peronosporales), with the apogamous Saprolegniales presenting conditions peculiar to themselves. But until we know more about these life-habits and the possibility of an organism passing from one condition into another, it is pure speculation to lay out lines of relationship. And again, we lack knowledge of the processes of oogenesis in a number of forms which may have important bearings on these problems of phylogeny (especially for Monoblepharis and Sphaeroplea).

In spite of the complications of the problems of phylogeny in the Phycomycetes, certain features stand out clearly which may be briefly summarized. The multinucleate character of the sexual organs in types of the Mucorales, Saprolegniales, and Peronosporales thus far studied, and perhaps some other forms as well (Monoblepharis) is likely to prove universal in these groups. Numerical reduction of potential gamete nuclei takes place through degeneration, a process of great physiological interest which deserves careful study. The suppression of the pore-forming activity gives the closed oogonium and antheridium peculiar to the fungal groups. The coenogametes characteristic of the Mucorales and also illustrated by certain of the Peronosporales (*Albugo Bliti*, *A. Portulacae*) are morphologically gametangia and probably have had their origin by the suppression of the processes of cleavage to form many gametes and their assumption as coenocytic units of sexual attributes. The Saprolegniales and Peronosporales exhibit the further peculiarity of

eggs differentiated around dynamic centers (coenocentra), with the specialization of a periplasm in some forms. Perhaps the highest expression of periplasmic development is the cellular envelope which finally invests the egg of Araiospora.

SUMMARY OF THE INVESTIGATION OF VAUCHERIA.

The oogonium arises as a process containing dense protoplasm with many plastids and nuclei. As the young structure increases in size, vacuoles develop in the protoplasm, which consequently forms a peripheral layer next the cell wall.

The number of nuclei is variable, but always large, probably ranging from 20 to 50. There are no mitoses in the oogonium.

The oogonium becomes separated from the parent filament by a cross wall which is developed between two plasma membranes that appear to be formed along the surfaces of flattened vacuoles.

The oogonium is multinucleate at the time the cross wall is formed; but even then there is evidence of the degeneration which becomes much more pronounced later.

In older oogonia the degenerating nuclei are found chiefly in the periplasm. They become exceedingly small, the nuclear membrane disappearing first, and finally nothing remains but granular matter, apparently nucleolar, which is finally lost in the cytoplasm of the cell.

A single nucleus survives the general processes of degeneration. This becomes the gamete nucleus and takes its position near the center of the egg, which is probably the situation most favorable for its growth. There is apparently no coenocentrum in the egg of Vaucheria, but the surviving nucleus frequently lies in a mass of rather dense protoplasm which may readily represent a center of metabolic activity.

There are excellent reasons for believing that all of the nuclei in the young oogonium are potentially gamete nuclei, and that the selected egg nucleus owes its survival and later growth entirely to the good fortune of a favorable situation in the cell.

The gamete nucleus grows rapidly until it is finally three or four times the size of the nuclei in the young oogonium. There is a marked increase in the amount of chromatin, which fills the interior

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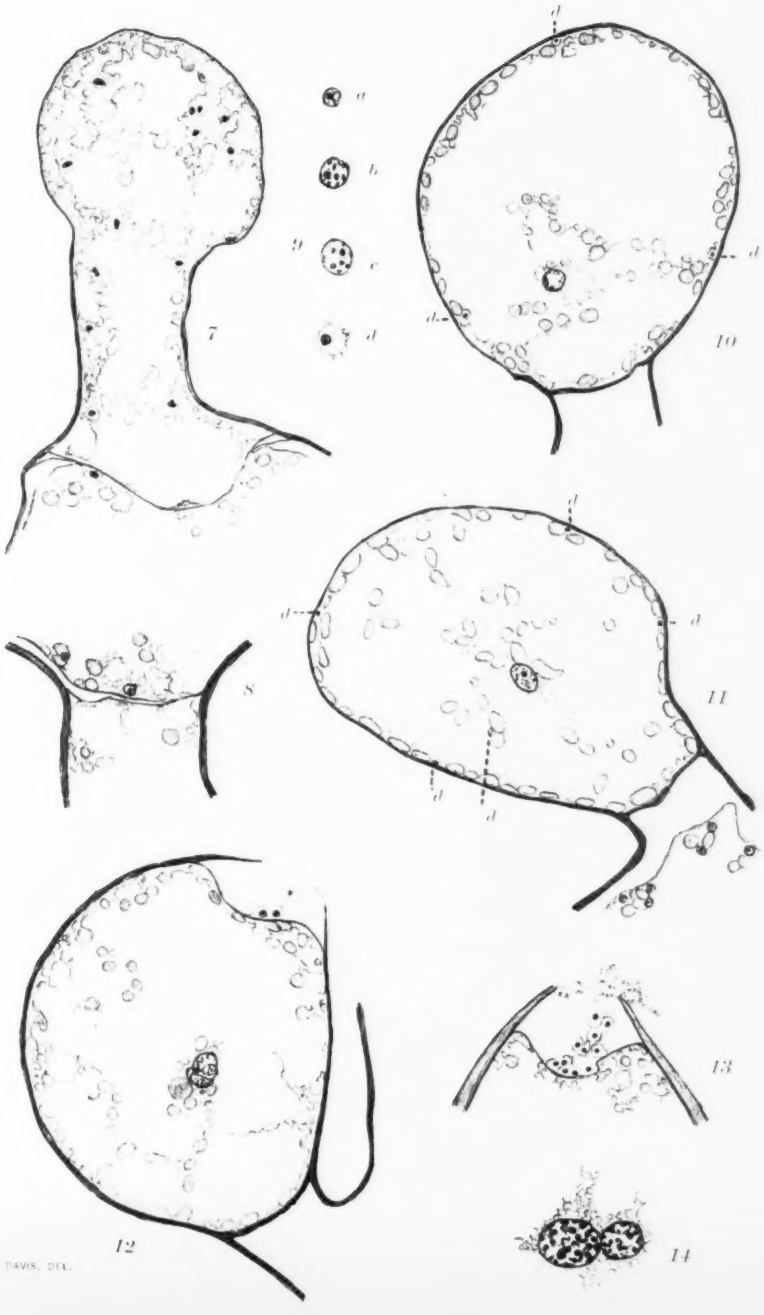
DAVIS on VAUCHERIA.



DAVIS on VAUCHERIA.

of the nucleus with numerous small granules on a delicate linin network.

After fertilization the nucleus of the sperm passes to the center of the egg, where it increases in size at the side of the female nucleus in the same region of dense protoplasm. The two sexual nuclei fuse slowly when both are approximately of the same size.

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EXPLANATION OF PLATES VI AND VII.

The sections were cut 5 μ thick and stained with safranin and gentian violet. All figures were sketched with an Abbé camera under the Zeiss apochromatic objectives 2^{mm} or 1.5^{mm} in combination with compensation oculars. The magnification is as follows: *figs. 1–2*, ×500; *figs. 3–8* and *10–13*, ×667; *fig. 9*, ×2,000; *fig. 14*, ×1,334.

FIG. 1. Oogonium beginning to develop.

FIG. 2. Young oogonium.

FIG. 3. Young oogonium, large vacuoles forming.

FIG. 4. Oogonium, flattened vacuoles marking the positions where the cross wall would have been formed.

FIG. 5. Oogonium, delicate cross wall just formed.

FIG. 6. Oogonium, delicate cross wall, nuclei showing signs of degeneration.

FIG. 7. Oogonium, cross wall, nuclei degenerating.

FIG. 8. Cross wall between two plasma membranes.

FIG. 9. A series of nuclei from the same section to illustrate the process of degeneration with the gradual disappearance of the chromatin and the fading of the nuclear membrane: *a*, from antheridium; *b*, from just below the antheridium; *c*, from near the oogonium; *d*, from within the oogonium.

FIG. 10. Old oogonium with gamete nucleus in the central mass of protoplasm and degenerating nuclei (*d*) in the peripheral layer.

FIG. 11. Oogonium older than *fig. 10* and probably mature, remains of degenerating nuclei (*d*) in the peripheral layer of protoplasm.

FIG. 12. Fertilized egg, gamete nuclei fusing in a mass of dense protoplasm.

FIG. 13. Tip of oogonium showing mass of sperms in the slime at the opening.

FIG. 14. Gamete nuclei showing comparative size and general similarity in structure when about to fuse.

A STUDY OF TILLANDSIA USNEOIDES.

FREDERICK H. BILLINGS.

(WITH ONE FIGURE AND PLATES VIII–XI)

Tillandsia usneoides, popularly called "long moss," "black moss," or "Spanish moss," is the most widely distributed representative of the tropical and subtropical family Bromeliaceae. According to SCHIMPER (1) it extends from southern Virginia, its northern limit, as far southward as the Argentine Confederation. It forms everywhere a conspicuous and characteristic object of the landscape, its long gray festoons adorning not only trees of the virgin forest but many cultivated ones as well. Although the beauty of the landscape is enhanced by its presence, its growth upon ornamental trees is regarded often with apprehension, a common impression being that it lives parasitically. A most casual examination, however, will reveal the fact that the moss is in no way connected with the tree, but merely wraps its dead, wiry stems loosely around the twigs in order to support itself. Old festoons which have hung in the same place for years occasionally show a connection with the bark, the annual growths of the limb finally enclosing some of the decorticated moss stems; much in the same way that an old horseshoe hung astride a branch and left unmoved for a long time will be partially enclosed.

An indirect cause of the popular belief in the parasitism of Tillandsia is its preference for sunny exposures. This habit would tend to keep it from trees having a dense shade. In dark forests it hangs suspended from the higher limbs of tall trees, especially those that are dead. Many a cultivated tree when in perfectly healthy condition possesses too dense foliage to serve as a host for Tillandsia, but if for some reason the supply of leaves should be reduced, the light conditions might be such as to make the presence of the epiphyte possible. Should it make its appearance, the owner of the tree would be very apt to regard the moss as the cause rather than the result of the reduced foliage. A proof of the true epiphytism of the plant is its long-continued and vigorous growth upon decorticated limbs of dead trees. Near Baton Rouge are many such trees, killed by girdling long ago,

yet supporting a large quantity of moss. In order to demonstrate experimentally that the moss can live solely on what it derives from air and rain, some festoons were supported by twine and hung from some branches of a tree upon which moss was already growing. As was expected, the festoons produced normal flowers, gave rise to new growth, and at the end of eighteen months looked as vigorous as any on the tree, though they came at no time in contact with it.

Because Tillandsia has no influence as a parasite, it does not follow that it exerts none in other ways, yet to just what extent it affects a host tree is at present difficult to say. Aside from the slight damage done in breaking twigs and small branches by its weight, it is doubtful whether such objections as shading and cutting off the supply of air are really worthy of consideration. It is almost certain that these objections are not sufficient to explain a reduction in foliage that people so often ascribe to the presence of the moss. It is realized, however, that this problem can only be answered satisfactorily by experiments extending over a considerable number of years.

The problem of the distribution of *T. usneoides* upon the various species of trees is one of the first to force itself upon the observation. That certain trees of a given locality are abundantly supplied while others not far distant are not, is a well-known fact. One factor in the case has already been mentioned, and that is the light relation. But there are others to be considered, and the most important perhaps is concerned with the method of dissemination. The epiphyte is not usually propagated by seeds but by fragments of festoons, which being somewhat heavy cannot be carried far except in a very high wind, or by birds, which according to SCHIMPER (1) in some regions utilize the plant in building their nests. There is a good chance, therefore, for a tree a little distant from others bearing the moss not to receive its first detachment of the epiphyte.

The character of the foliage also plays a part, in that a tree with leaves densely crowded on the outermost twigs would scarcely permit a wind-blown fragment of moss to hook itself to the branches, but would shed it. SCHIMPER (1) observes in this connection that "Bäume mit sehr dichtem Haube entbehren der Sonnenepiphyten beinahe gänzlich." According to PEIRCE (2) *Ramalina reticulata*, a lichen having a habit and mode of dissemination similar to *T. usneoides*,

is found more frequently on deciduous than on evergreen trees, because, as he explains, the foliage of the evergreen trees interferes with its reaching the branches. The umbrella tree (*Melia Azederach*) has a remarkably dense foliage and is almost universally devoid of moss, yet near the university is a tree of this species with a scanty supply of foliage and an abundance of moss. It is reasonable to conclude that any tree furnishing proper conditions for attachment and growth may become a host of the epiphyte.

The source of the water supply of Tillandsia is atmospheric precipitation, as in all epiphytes. Dissolved in the water are the necessary salts which have been dissolved by the rain from the dust in the air. Perhaps an equally fruitful source of salts is in many cases the washings from the tree, which in dry weather may accumulate much earthy material in the form of dust upon its branches. The plant itself even serves in collecting dust on account of the scaly surface, so that when wet the deposits beneath the scales yield a small amount of soluble material.

A most remarkable characteristic of Tillandsia is its ability to retain water. The absorption of water is accomplished over the entire surface of the living parts by means of scales, as will be described further on, its retention being accomplished also by the scales, and of course by the cuticularized epidermis. It is much easier to understand how a melon cactus with its globose form and consequent minimum surface and enormously developed water-storage tissue can resist prolonged drouth than it is to see how Tillandsia with its small cylindrical leaves, much greater surface exposure, and comparatively small storage facility can, without any water supply, endure drouth. A small festoon was hung in a closed dry room for nineteen days without water. It lost 23 per cent. in weight during the time, but when placed in water it absorbed as much as it had lost, and remained a healthy plant, showing that it had not really suffered injury by exposure to the drouth. There is occasionally, of course, a similar drying process in the open air when drouth occurs. During the dry spell in the spring of 1902, moss plants were known to have been subjected to two months of rainless exposure without injury.

From an economic standpoint, Tillandsia is of some commercial value on account of its mechanical tissue. This forms a central

cylindrical strand composed of reduced phloem and xylem, surrounded by a mass of thick-walled sclerenchyma fibers. When the parenchymatous cortex is removed, the sclerenchymatous axis remains as a tough elastic fiber, which serves as a packing in upholstery. The so-called curing process is a means of eliminating the parenchyma. One method largely employed is that of burying the moss in trenches or pits, allowing it to remain till the cortex is dead and in a condition to be removed easily.

DEVELOPMENT OF THE EMBRYO SAC.

The primordia of the ovules arise on the innermost wall of each loculus of the tricarpellate, superior ovary. By a one-sided growth each primordium becomes bent toward the base of the ovary, developing into the anatropous type of ovule. When the bending has reached an angle of about 90°, the nucellus appears as a hemispherical mass of cells, at the base of which can be seen the beginning of the inner integument. Imbedded under two layers of nucellus cells, the single archesporial cell becomes differentiated in the usual way, by its slightly larger size and greater staining capacity (*fig. 2*). As the ovule increases in size, the nucellus elongates, the outer integument appears, and the archesporial cell enlarges considerably, especially in length. There is no parietal cell formed, but by multiplication of cells the nucellus over the archesporial cell forms an additional layer, making three (*fig. 3*). The archesporial cell is now much elongated, and occupies the central region of the nucellus. It is filled with granular, longitudinally-striated cytoplasm, and has a relatively large nucleus. The first and second divisions of this nucleus probably give rise to the gametophyte generation. Only one spindle of the first division was observed, and it was but little more than one-third the length of the cell (*fig. 4*). The chromosomes were short, and closely crowded at the equatorial plate. The conditions were altogether unfavorable for ascertaining their number on account of the small size of the figure. The number, however, was definitely made out from the second division of the pollen mother cells, and was found to be sixteen. A protracted search failed to yield a nuclear figure which definitely showed the chromosome number in the sporophyte, though considerably over sixteen were observed.

The first division of the archesporial cell is usually followed by a transverse wall and a resting condition of the nuclei (*fig. 5*); but a single case was observed, as reported by SMITH (3) for *Eichhornia crassipes*, in which a row of four nuclei was formed without separating walls (*fig. 7*). In Eichhornia the absence of the walls is said to be the rule, but in Tillandsia it is the exception. The division which gives rise to the third and fourth megaspores, thus completing the axial row, will be seen from *fig. 6* to be in the cell nearest the micropyle. In the meantime, the basal of the two proximal megaspores begins to elongate, and is destined to develop into the embryo sac. A vacuole is formed in this cell as it pushes outwards crushing the other three megaspores, whose contents soon show evidence of breaking down. The remaining stages in development are the familiar ones of complete absorption of the non-functional megaspores by the functional, and the internal division of the latter into eight cells. The two cells that are to form the synergids soon come to possess larger nuclei than does the egg cell. The egg nucleus in fact is smaller than is customarily observed. In the completed embryo sac, the egg often lies against the wall of the sac near one synergid, but may occupy a position between the synergids. The polar nuclei usually approach each other and fuse near the antipodal region (*fig. 14*). The antipodals occupy a pocket at the extreme end of the sac.

FERTILIZATION.

The pollen tube passes through the micropyle, penetrates the nucellus, and enlarges as it enters the embryo sac. It does not appear to pass between the synergids, but to one side of them, one synergid being disorganized in the process. The two male nuclei which have arisen from the generative nucleus during the development of the pollen tube lie near together and a little in advance of the tube nucleus. In no case observed did the male nuclei show the much elongated, spermatozoid-like form so often described for other plants. In *fig. 15*, which represents the tube before its rupture, they are elliptical; but when discharged they are slightly more elongated and may have pointed ends. The place of discharge may be either at the end of the tube or lateral, though near the end (*figs. 16–19*). The tube nucleus is usually to be seen at the time of dis-

charge of the male nuclei, but may be absent later, which would indicate that it too was ejected. In one instance (*fig. 19*) the nucleus was observed after ejectment. The male nuclei are of about the same size and appearance, and leave the pollen tube at about the same time. The nucleus which is to fuse with the endosperm nucleus can be seen in various stages of its passage to the antipodal end of the embryo sac. There is no evidence that either nucleus increases in size after leaving the pollen tube. The time of fusion with the polars may be either before or after their complete union with each other; in *fig. 18* it is before. In *fig. 18* the fusion of the two male nuclei with the egg and polar nuclei respectively is seen to be simultaneous. After fertilization the egg secretes a wall about itself and rests for a time.

The occurrence of darkly-stained bodies so frequently seen in pollen tubes has been noted in Tillandsia. They were observed in the microspores before germination, which would account for their presence in the pollen tube.

THE SEED.

The most noticeable change that results from fertilization is the extensive elongation of the entire ovule. Part of the growth is due to enlargement of the embryo sac and its surrounding integuments, while the remainder is traceable to elongation of that part of the outer integument which is prolonged above the body of the ovule. The inner integument does not appear to elongate at all, hence the opening of the micropylar canal comes to lie far below the opening of the canal formed by the outer integument (*fig. 22*). A similar elongation of the outer integument was observed in *Puya chilensis* by HOFMEISTER (**4**).

Accompanying the growth of the embryo sac is the development of the endosperm. It begins to form at once after fertilization, and the nuclei resulting from the first divisions of the endosperm nucleus take position at either end of the sac, leaving, however, a few to form a thin parietal layer between. At the antipodal end, cell formation with walls begins at once, and a number of large cells form a tissue which stands out conspicuously in the cavity of the sac, which otherwise contains only a few free endosperm nuclei. At first this tissue

was taken as an extraordinary development of antipodals, but cases were found where the three degenerate cells were lying beneath the tissue in the small pocket at the end of the embryo sac. The free endosperm nuclei gradually gather in increasing numbers against the endosperm tissue, finally forming walls about themselves but remaining readily distinguishable from the other tissue (*fig. 24*). The functions of the two tissues appear to be somewhat different. The originally formed cell-compact retains its richness of protoplasmic contents during the development of the embryo, probably serving in the conduction of food materials to the later formed tissue adjoining it, which soon shows signs of containing food deposits. The reserve materials thus laid down are not utilized by the embryo before seed germination, but exist as the endosperm of the ripe seed. The endosperm at the micropylar end of the embryo sac does not develop in large quantity, forming a tissue about the embryo only after the latter attains a considerable size.

The egg cell remains dormant for a time after fertilization. In 1903 the period of blossoming lasted (at Baton Rouge) for a month following the middle of May. Material gathered about the first of July showed egg cells undivided, as well as embryos of only a few cells. Growth during the summer is slow, small embryos being found in material gathered about the tenth of August. It was not till the middle of September that large ones were observed, and even then there was much diversity in size.

The first wall formed in the division of the egg cell is transverse, as is the second one also. The proembryo of three superimposed cells is therefore not different from the type that holds in so many monocotyledons. The divisions immediately following, however, vary considerably in sequence.

The middle segment may divide sooner than the terminal (*fig. 28*), or the reverse may be true (*fig. 27*). The basal segment divides sooner or later by longitudinal walls into four cells—a variation from the Alisma-type, in which the segment is unicellular and vesicular. The terminal segment divides by longitudinal walls to form the quadrant, and by transverse walls to form the octant. The latter walls instead of being precisely transverse may be oblique (*fig. 34*). In many older embryos the arrangement of the cells in this segment

indicates that the walls in question were originally oblique or else became so by unequal growth in different parts of the embryo (*fig. 36*). The dermatogen usually forms first in the terminal segment. To distinguish the middle from the terminal segment soon becomes a difficult matter, but from the position of the concavity in which the stem apex is developed, it is safe to say that the apex arises from the middle and the cotyledon from the terminal segment, as in Alisma. The middle segment also gives rise to the root-tip, hypocotyl, and part of the suspensor. A short time before the differentiation of the stem tip in the lateral depression, the region adjoining and outside of the area where the stem tip is to appear grows upward into a ridge of tissue, which in the mature embryo encloses the growing point completely. If the figure of the embryo of Guzmannia, as shown by WITTMACK in Engler and Prantl's *Natürlichen Pflanzenfamilien* be compared with that of *T. usneoides* (*fig. 40*), the resemblance will at once be apparent. It will be noticed that what I have called cotyledon in Tillandsia is called scutellum in Guzmannia, the term cotyledon[1] being reserved by WITTMACK for the small outgrowth labeled *c*, near the stem apex. It is probable that the author in thus naming the two organs scutellum and cotyledon only wished to emphasize the difference in function, one as an organ of absorption, the other as a rudimentary leaf, at the same time recognizing the two as homologous with the cotyledons of the dicotyledons. From a study of the seed germination of *T. usneoides*, however, it will be seen that it is extremely doubtful if the organ named cotyledon in Guzmannia is really such. Further discussion of this point, however, will be postponed till seed germination is considered.

When the embryo of Tillandsia is about three-fourths grown, there occurs a degradation of certain cortical cells of either the root or the end of the hypocotyl nearest the root-tip. The cells in question show at first a contracted protoplast, with incapacity to stain deeply, and by the time the embryo has reached its full size almost a complete absence of cell contents (*fig. 42*). This phenomenon undoubtedly stands in intimate relation with the complete atrophy of root that obtains in the mature plant.

[1]The index letter *c* in the description of *fig. 19, G* of the Bromeliaceae has been found through correspondence to indicate cotyledon.

Dispersal of seeds in the Tillandsia is accomplished by the assistance of long delicate hairs that beset the seed coat. These arise by elongation of the cells of that part of the outer integument which forms a portion of the body of the seed, and also from that part which extends to the funiculus. The hairs not only assist in wind transportation, but are also of use to the seed in enabling it to adhere to bark or festoons of moss. The adaptation for effective adherence consists in closely appressed barbs attached to the hairs at intervals (*fig. 44*). Soon after the opening of the capsules, numerous instances of seeds clinging tightly to limbs and to moss festoons may be observed.

The time of discharge of seeds is in March (at Baton Rouge). I have no data as to possible variation of this time in localities widely distant, but suppose it is nearly uniform for the southern states. March, of course, is an unusual month for dehiscence of fruits in the north temperate zone, but in Tillandsia it stands in close relation to another property not generally possessed by seeds in temperate climates, that is, quick germination. Though lack of facts forbids positive statement, it may be conjectured that this relationship originated from ancestors living in tropical lowlands, where a dormant period to withstand unfavorable conditions is unnecessary.

GERMINATION OF THE SEED.

Tillandsia produces seed in considerable quantity each year. Just what proportion contains fully-matured embryos has not been ascertained, but there is no doubt that a large percentage have them. The embryos appear perfectly normal, with the exception of the dead cortical cells in the root or hypoctyl, and show no apparent reason why they should not give rise to seedlings. The experience of investigators, however, has been that seeds produced by the epiphyte are worthless, a condition which has arisen through the introduction of a vegetative mode of reproduction, whereby seed-production has degenerated. Nevertheless, I made efforts to induce seeds to germinate by placing them in a germinator, but without success. MEEHAN (**5**) reports having found the seed germinating in the hollow crotch of a tree in which vegetable mold had collected. He says that from the seedlings or young plants proceed stolons or runners, having buds

every few inches, which push out into leaves and stems to form the gray-green moss. SCHIMPER (1) succeeded in finding one seedling, but he gives no description of it. MEZ (6) states he was unable to obtain any seedling at all. Realizing that the observations of MEEHAN were worth consideration, I searched crotches of moss-laden trees, in which plenty of vegetable mold had collected, but without success.

FIG. 1.—Seedlings of *Tillandsia usneoides;* on the right is a cluster of seedlings still attached by their coma to a partially opened capsule; near the top of the shoot on the left a seedling is adhering to the scaly surface.

I then planted seeds in the mold, but they could not be induced to germinate. On April 6, 1903, I observed Tillandsia seedlings for the first time, and they were projecting from a partially-opened capsule (*fig. 1*). Out of the nineteen seeds in the capsule, thirteen had developed into seedlings. They were held in place by the tuft of hairs from the testa to which they still adhered. An examination of moss festoons was then made, with the result that many little

seedlings were found either still attached to the capsules, or else hanging to the scaly stems and leaves of the mother plants. In every case the seed coat still adhered to the base, or root-end of the seedlings, so as to enable the coma to keep them from falling to the ground, which they certainly would have done without this provision. When it is remembered that the capsules dehisced in March, and the seedlings were found early in April, it will be seen that germination followed dehiscence quite closely. Of course the early growth was attained at the expense of the endosperm, but when it was exhausted, continued growth, which would naturally be expected from healthy looking seedlings, failed to occur. Material gathered in the summer and autumn yielded the usual crop of seedlings, but in no case were any found that were larger than those found in April. Festoons gathered the middle of January, nearly a year after the capsules opened, had numerous little seedlings hanging to them, all healthy looking, but no larger than any observed before them. It is expected that when the warm weather of spring comes, when Tillandsia puts forth its most vigorous growth, the seedlings also will increase in size. The question naturally arises here, why Tillandsia seedlings are not to be seen in all stages developing into mature plants, counting of course those which germinated previous years. As such is not the case, it can only be conjectured that, as the spring of 1903 was an unusually rainy one, the conditions for germination were especially favorable.

Seedlings exhibiting various stages in germination were imbedded in paraffin and longitudinally sectioned. In the earliest stage (*fig. 45*) the first leaf shows only a slight growth, the stem apex is still undifferentiated, while from the axil of the ridge of tissue that enclosed the stem apex, or else from its inner surface, a pair of organs have arisen. It is believed that the presence of these organs throws some light upon the morphological nature of the ridge of tissue. If a section is made through the nodal region of a mature plant (*fig. 49*), it will be seen that the leaf sheath which encloses the lateral shoot and main axis is double. The doubling is not due to splitting of a tissue once entire, but to bifurcation. A section through a very young sheath (*fig. 49a*) reveals an outgrowth, one to several cells in extent, from which a double layer of cells arises. These soon separate to

form the double sheath. In older stages the base of the sheath is composed of many cells in width, so that the sheath appears no longer to originate as a bifurcation of a single organ, but rather as two distinct organs. Both organs or portions of the sheath may develop equally, though it more often happens that one portion becomes larger than the other. Occasionally, the inner scarcely develops at all, but remains a tiny rudiment.

The sheaths which arise in the seedling develop precisely like those in the mature plant and differ from them in no respect. The two organs that originate on the ridge of tissue, therefore, may be regarded without hesitation as the first sheath, and as every sheath appears in connection with a leaf, that leaf must be the cotyledon. From the section of the mature plant it will be noticed that the bases of each leaf and its sheath are at the same level on the axis. If a difference in level should occur, however, whereby the base of the sheath were elevated above that of the corresponding leaf, the cell growth producing that elevation would originate from the cortical parenchyma lying immediately under the sheath. The parenchyma would give rise to a ridge bearing the sheath upon its summit. Such an occurrence does not of course actually take place in the mature plant, but it is believed that it is in such a way that the ridge of tissue originates in the embryo. Reasons for coming to this conclusion are based upon the position of the first sheath. While the inner portion of the sheath may grow from the crotch at the base of the ridge of tissue, the outer, and sometimes the inner also, is attached to the ridge upon its inner surface. The outer portion may in fact arise from the summit of the ridge. The base of the sheath, therefore, is on the whole raised above that of the cotyledon, the elevation being accomplished through growth of the subjacent parenchyma. Thus there develops a special organ which serves a special purpose, perhaps as protection to the stem apex, and which must therefore be regarded as an embryonic structure without an exact counterpart in the adult plant. It cannot be a leaf, or a cotyledon, because a leaf does not bear such a relation to its sheath. A leaf and its sheath always develop with a growing point between them, so that they can never join in a median section. CAMPBELL (**7**) calls a similarly placed though less extensive outgrowth in the embryo of Sparganium a sheath. While it does not require a

stretch of the imagination to consider the growth in question a sheath, there is at least one objection to this solution of the problem. The development of the sheath shows that it appears as a bifurcated organ almost from its incipiency, and that the base, at first narrow, subsequently increases greatly in width. Quite the reverse would be true in the embryo if the organ enclosing the growing point were regarded as a sheath, for the basal portion is first enormously developed, leaving the upper bifurcated portion to appear comparatively late.

The stages in germination are shown in *figs. 45–48*, which should be compared with *fig. 49*. The latter exhibits a difference in relative time of differentiation of stem and leaf apex as compared with the seedling. In the mature plant the leaf is still quite small when the stem apex becomes distinguishable at its base, while in the seedling the leaf first attains considerable size.

THE FLOWER.

The flowers, which are produced in considerable quantity in May and June, present little of special interest. Each flower has a calyx of three sepals, and a corolla of three green petals. Having a fragrant odor, it is possible that it is visited by insects, though no information has been collected by me on the subject. Thrips, however, inhabit many of the flowers and puncture the style in order to deposit an egg at its base. It is possible, therefore, that they may serve in cross pollination.

Although the flower appears to be terminal, it is regarded by MEZ (**6**) as a reduced indeterminate inflorescence. An examination of preparations made longitudinally through buds bears him out in his statement, for a growing point of considerable size is present, though having dead meristem tissue.

THE LEAVES.

The leaves of *T. usneoides* are acicular and with an approximately semicircular cross section. The epidermal cells do not have specially heavy walls, nor are the inner ones thicker than the outer, as in certain other Bromeliaceae. Sections through the leaf show it to have three fibrovascular bundles, each surrounded by a tissue composed of thick-walled sclerenchyma fibers (*figs. 50, 51*). The principal portion

of the leaf is composed of parenchyma cells which do not show any differentiatiation at all into palisade and spongy tissue. While the cells have the shape of those in typical spongy tissue, the large intercellular air spaces characteristic of most mesophytic leaves are here replaced by small ones, giving the whole tissue a much more compact appearance. Not all of the parenchyma cells contain chloroplasts, for there are interspersed cells without them, whose function is that of water-storage, having walls provided with large pits which facilitate the passage of water from one cell to another.

Aside from acting in the capacity of mechanical tissue, the vascular system has undergone a process of degeneration. The necessity for a functional xylem with its transpiration stream is eliminated by the fact that there is a complete absence of roots, and also by the fact that the water-absorbing organs, the scales, are found over the entire exposed surface with the exception of some of the floral organs. There would appear also to be no need for a functional phloem since all living cells either contain chlorophyll and are exposed to light, or else are approximate to those containing chlorophyll.

THE CHLOROPLASTS.

One of the most interesting features of the leaf is the structure and behavior of the chloroplasts. These bodies, instead of exhibiting the more or less homogeneous structure observed in most chloroplasts, are seen to be composed of masses of smaller chloroplasts, measuring about 2 μ long and about a third as wide (*fig. 52*). While a very few cells in every cross section of the living leaf contain chloroplasts of the usual type, the vast majority of them contain such as have been described above. The little chlorophyll bodies have almost, if not quite, the minuteness of bacteria, and for convenience will be spoken of as *microchloroplasts;* the larger bodies, of which they appear to form a part, being distinguished as *megachloroplasts*. The true significance of the formation of the microchloroplasts will be readily seen when it is stated that they may not remain in bunches (*fig. 52*), but can and often do separate from one another till the entire cytoplasm of the cell becomes dotted with them (*fig. 53*). Under a low magnification such a cell appears uniformly green throughout. They even enter the vacuoles, where a lively Brownian movement is set up.

It was at once suspected that the various phases in distribution of the microchloroplasts were conditioned by the light intensity, and hence their movements could be made subject to control. Festoons of Tillandsia accordingly were placed under different conditions varying from darkness to direct sunlight. Those placed in darkness were allowed to remain there 24 to 30 hours, and a similar period of exposure was allotted to festoons hung in the shade. Those exposed to direct sunlight were hung up early in the morning. All were examined during the hours between 11:30 A. M. and 3:00 P. M.

The examination was made by sectioning numerous leaves of various ages, and from as many different regions of each festoon as possible. Plants were also sectioned at different times of day and also at night. The results in every instance were approximately the same. Sections were obtained from plants under the varying conditions of light intensity used in the experiment; sections in which the megachloroplasts were present; in which they were in the process of disintegration into microchloroplasts; in which there was distribution of the microchloroplasts uniformly through the cell; and in which all the foregoing stages were present in the same section. In fact, the same leaf varied in these respects in its different portions. There seemed to be no method of telling before examination just what condition the chloroplasts would be in. One of the best instances of complete uniformity of distribution of the microchloroplasts throughout the cytoplasm was obtained from the tiny leaf of a seedling. That the disintegration of the mega- into microchloroplasts is not the result of injury due to sectioning may be proven by an examination of the entire leaf through the epidermis. Sections also cut thick contain in their centers cells untouched by the razor.

Homogeneous chloroplasts of the usual type were found which showed evidence of undergoing division. Megachloroplasts, in which the microchloroplasts were distinctly visible, were also found showing a deep constriction as though they too were undergoing fission.

Owing to the difficulty of observing well the interior of the leaf through the overlapping scales, it was not ascertained whether the microchloroplasts return to form megachloroplasts or not; but if so it seems certain that the latter would not be constructed of identically the same microchloroplasts a second time.

It is offered in explanation of this interesting condition of affairs that the supply of light of Tillandsia is considerably diminished by the presence of the overlapping scales, which are necessary for water absorption and for protection against too rapid transpiration. In order to meet this diminution, it not only prefers sunny exposures, but has modified its chlorophyll-bearing apparatus by causing it to occupy a much larger area in order to utilize to better advantage such light as penetrates to the interior of the leaf.

It may be stated here that precautions were taken to examine healthy festoons removed directly from moss-laden trees. In some instances these were examined immediately after such removal, lest confinement in the laboratory should in some way induce pathological conditions.

THE SCALES.

The scales cover the entire living exposed portion of the plant with the exception of the corolla, stamens, ovary, and a portion of the calyx. Each scale develops from a single epidermal cell, the early divisions of which occur while the young leaves and stems are included within the leaf sheath. The first division is transverse (*fig. 55*). The proximal cell thus produced remains undivided, the distal dividing transversely till four cells are produced, of which the lower three form the stalk of the scale (*fig. 57*). The outermost hemispherical cell becomes divided into four cells by two longitudinal walls perpendicular to one another (*figs. 58* and *63*). By periclinal walls a central group of four cells becomes separated from four outer ones (*fig. 64*). The central cells divide no further. The outer ones divide by periclinal walls to form two concentric rows (*fig. 65*). The cells of both rows become eight in number by anticlinal walls, the inner row undergoing no further division, but the outer, by another set of anticlinals, finally has sixteen. A fourth concentric row is then formed by periclinal walls from the outermost sixteen cells. The three inner layers consist of four, eight, and sixteen cells respectively, which numbers remain constant, but the fourth layer undergoes repeated divisions till a large number of cells are produced (*fig. 67*). These last lengthen greatly and form the wing of the scale. The surface view of the mature scale is seen in *fig. 68*, the longitudinal section in *fig. 70*. All of the cells but the stalk cells and the original

basal cells undergo thickening of their walls in certain portions and lose their cell contents.

SCHIMPER (1) was the first to call attention to the water absorptive function of the scales, and his experiments along this line were so complete as to leave little else to be done. That the leaves of Tillandsia can absorb water is easily demonstrated either by wetting them with water and then watching it disappear, or by noting the weight before and after allowing them to remain a short time in water. That the channel of absorption is through the scales is shown by using colored water, which stains the stalk cells. Unlike most similar appendages of the epidermis, the scales do not hinder the leaf from becoming wet, but actually conduct water into the interstices beneath them. When dry, the leaf is of a gray color, due to the air enclosed by the scales, but when wet, the air is replaced by water, and a deep green color results. From an examination of *fig. 70* it will be seen that the outer walls of the scale are thickened. When water is absorbed by the cells with thickened walls, they become turgid, expand below, and raise the wing of the scale well above the epidermis (*fig. 69*). The water absorbed by the outer cells of the scale passes to the stalk cells, which have thin walls and rich protoplasmic contents. Through these it passes through the basal cell to the water-storage cells of the parenchyma. If the plant be soaked in dilute potassium iodid solution for a day, the walls of the stalk, basal, and neighboring parenchyma cells will be stained. It should be noticed that no ordinary type of epidermal cell with its thickened cuticularized wall separates the scale from the parenchyma. The cell that represents the epidermis beneath the scale is the basal cell resulting from the first division of the epidermal cell that gave rise to the scale. The walls of this basal cell are thin and uncuticularized. If a scale whose wing is raised well above the epidermis by the turgescence of its cells be treated with glycerin, the contraction due to loss of turgescence will draw the scale close down against the epidermis. This illustrates the process that takes place when scales become dry from evaporation, as occurs in nature. Such a process cannot but assist the epidermis in checking transpiration, so that the scales may be considered not only as organs of absorption, but as serving to prevent too rapid escape of the water they have been instrumental in bringing into the plant.

The effect of an absorptive system extending over the entire surface has already been mentioned in the reduction of the mechanical and conductive tissues. As such reduction is found mostly in submerged hydrophytes, it will be seen that *T. usneoides* behaves in these respects much like such plants.

The scales stand in connection with the water-storage tissue. The cells of this tissue lie well distributed among the chlorophyll-bearing cells and keep them in a state of turgescence. Even after a plant has lost one-fourth of its weight by transpiration, and the leaves have become grooved by contraction, the chlorophyll-bearing parenchyma is unhurt. It is believed that the leaf shrinkage is due to a partial collapse of the storage tissue upon loss of water, rather than by decrease in turgescence of the green parenchyma. There is no evidence that the plant undergoes desiccation and subsequent revival, as in the case of *Polypodium vulgare*.[1]

THE STOMATA.

In addition to protection afforded by scales, hairs, and thick-walled epidermal cells, xerophytes sometimes guard against too rapid transpiration by means of the position and structure of the stomata. Sunken stomata, or those vestibuled by an epidermal air space, itself with a narrow opening to the exterior, are all well known. In some xerophytic plants the usual closing of the pore by the guard cells is assisted in its function of checking transpiration by modifications in neighboring parenchymatous or epidermal cells. In *Kingia australis*, for instance, there is, according to TSCHIRCH,[2] a large intercellular space adjoining the stoma, partially filled with coiled cellular

[1] Since this paper went to press, one by MEZ (**9**) has appeared on the physiology of water absorption in certain species of Tillandsia, among them *T. usneoides*. MEZ corrects SCHIMPER'S observations as to the details of the absorptive process, claiming that the empty cells of the scale do not contain air, but are collapsed when the surface of the plant is dry. The thickened part of the scale swells when wet, raising it and causing the lumen to reappear in the collapsed cells. Water passes from exterior capillary spaces into the partial vacuum through thin places in the cell walls, whence, from the filled cells as reservoirs, the water is taken up and passed into the mesophyll by the stalk cells (*Aufnahmezellen*) through the usual process of osmosis. MEZ describes the scale of *T. usneoides* as having only one stalk cell instead of three. While it is true that two of the cells are very thin, their presence can readily be made out in good sections of mature scales and still more readily in sections of young ones.

[2] HABERLANDT, G., Physiologische Pflanzenanatomie. 2d ed. p. 399. 1896.

outgrowths of the parenchyma. The outgrowths do not stop, but merely hinder transpiration. *Xanthorrhoea hastilis* exhibits a similar contrivance. *Camellia japonica* and *Prunus Laurocerasus* have the faculty of filling up the air space as a result of excessive drouth or by death of the guard cells. In such cases tylose-like processes occur which block up all gas interchange. *Pilea elegans* differs from those mentioned above in that certain subjacent parenchyma cells develop thickenings on their exterior walls. One of these finally pushes up against the pore of the stoma and effectually closes it. There is no movement of the parenchyma cell away from the stoma, hence the aperture is permanently closed. From an examination of *figs. 72* and *73* it will be apparent that Tillandsia presents a condition of affairs not widely different from that of Pilea. The principal difference lies in the fact that in Tillandsia the parenchyma cells undergo no thickening. Both longitudinal and cross sections through the leaf show outgrowths from the parenchyma cells lining the sides of the air space. The outgrowths turn upward and either stop up the opening of the stoma or else press directly against the guard cells. It will be seen that the enormously thickened walls of the guard cells preclude a possibility of change in their form. To show this experimentally some plants were placed in water and exposed to direct sunlight for a few hours. The leaves were then sectioned and the guard cells watched with a micrometer while glycerin was run under the cover glass. There was no measurable change. According to MEZ (**6**) the guard cells have lost the power of functioning, this power having been transferred to certain cells of the subjacent tissue which operate the passive guard cells, thus opening and closing the stoma. There are two cells which come in contact with the guard cell and may therefore be the means of moving it. One is the cell to which it is attached and which extends from the hinge to the inner face of the guard cell. This cell is usually continuous, but may be divided by a cross wall into two cells. Should this cell, which is epidermal, become turgescent, it would tend to raise the guard cell, swinging its free side outwards. Such a movement, however, would close rather than open the pore of the stoma. The hinge is quite thick and may be much thicker than any shown in the figures. If the epidermal cell is divided the division wall would effectually hinder any movement of

the guard cell. From these two considerations it would appear doubtful whether the guard cells move at all in either direction. Of course the glycerin experiment was repeatedly tried, but no motion was discernible. The only other cells which by contact with the guard cells can move them are the parenchyma cells whose processes push against the guard cells on the under side. It was at first thought that the parenchyma cells were operated by variations in turgescence of the epidermal cell, so that regarding the guard cells as immovable the epidermal cell would press downward upon the subjacent parenchyma cell during turgescence, and lower the process, thus unstopping the stoma. Out of a number of such processes only one reaches the center of the stoma, all the others being considered attempts that from necessity have failed. This explanation of the function of the parenchymatous outgrowth is plausible, to say the least, but it has not been experimentally proven by the glycerin test. Numerous instances were investigated carefully, but in not a single case did any of the processes change their position. It is here confessed that no reaction was noticed in any part of the stoma or adjacent tissue in response to the action of glycerin, nor was an instance found in fresh material where the guard cells appeared to be separated. The experimental demonstration of the presence of a mechanism in the stomata, therefore, has not thus far met with success.

Another explanation might be mentioned, in which the processes are to be considered attempts on the part of the plant to close the stomata permanently. It may be that not all the processes actually reach the center of the stoma and close it, so that, granted that a small opening exists between the guard cells, the number of functional stomata would merely be reduced. The total number of stomata per square millimeter was ascertained and found to be relatively small. The estimate was made by counting the number of stomata in each section of serial sections taken from a portion of leaf of known length. For instance, a piece of leaf 3^{mm} long contained 52 stomata. Calculating the surface from the circumference of the cross section, there would be 7 per square millimeter, or, in round numbers, 4,300 per square inch.

It must of course be taken into consideration that *sections* of living leaves were used for experiment and not entire ones. If variations in

the pressure of the water-storage tissue exert any influence on the opening and closing of the stomata it is very probable that the injury done to the tissue in sectioning would greatly interfere with the action of the mechanism.

HABERLANDT (8) figures the stoma of *Tillandsia zonata*, which in respect to guard cells, and their supporting cells, resembles that of *T. usneoides*. The guard cells have greatly thickened walls, and a thickened hinge. From Haberlandt's account it is evident that he does not fully comprehend the mechanism. In *T. zonata* no subjacent parenchyma is mentioned as taking part in the opening or closing of the stoma.

THE STEM.

Aside from the vascular region, the stem differs in no essential particulars from the leaves as to structure. The stem, of course, has the added function of support, so that there is developed between and around the bundles a thick tissue of sclerenchyma fibers (*fig. 74*). The fibers measure about 750μ in length. They do not impart rigidity, but flexibility and power to resist longitudinal strain. If a fragment of moss is blown from one limb of a tree to another, and succeeds in getting a hold, the cortex of that portion of the stem that passes over the limb dies, and then disintegrates, leaving the sclerenchymatous axis, which holds the plant in place for several and perhaps many years. It is upon the durability and elasticity of this tissue that the economic value of the moss in upholstery depends.

What has already been said in regard to reduction in the function of the xylem and phloem of the leaves could with equal truth be said about the stems. With a superficial absorptive system and no root, the xylem as a conductive system is useless. The pendent habit and method of dissemination are both closely associated with reduction in mechanical tissue, though they are more likely to be the result than the cause of the reduction. The parenchymatous cortex, as in leaves, is supplied with chlorophyll-bearing cells, all of which are exposed to light, so that a tissue like the phloem, to carry elaborated materials to cells distant from the center of photosynthesis, would be unnecessary.

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EXPLANATION OF PLATES VIII–XI.

FIG. 2. Ovule fundament showing archesporial cell.

FIG. 3. Young ovule at period just before first division of archesporial cell.

FIG. 4. Spindle of first division.

FIGS. 5–6. Stages in formation of axial row of potential megaspores.

FIG. 7. Megaspores without separating walls.

FIGS. 8–9. Enlargement of basal megaspore to form embryo sac mother cell.

FIGS. 10–14. Stages in formation of embryo sac.

FIG. 15. Pollen tube just after entering embryo sac.

FIG. 16. Fusion of polars before rupture of pollen tube: *s*, synergid; *e*, egg.

FIG. 17. Lateral discharge of pollen tube: *e*, egg; *t*, tube nucleus; *s*, synergids.

FIG. 18. Simultaneous double fertilization.

FIG. 19. Double fertilization with discharge of tube nucleus (*t*); *e*, egg.

FIG. 20. Fusion of male and endosperm nuclei.

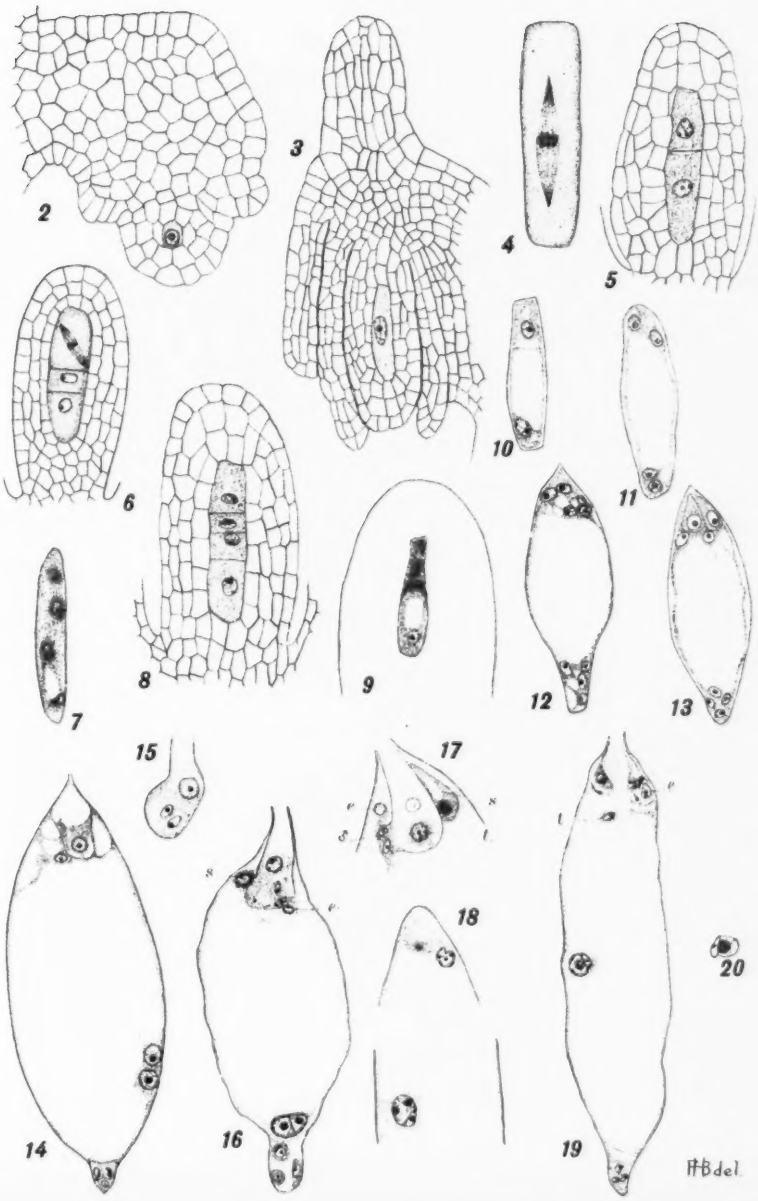
FIG. 21. Ovule at time of completed embryo sac.

FIG. 22. Elongation of ovule and outer integument after fertilization.

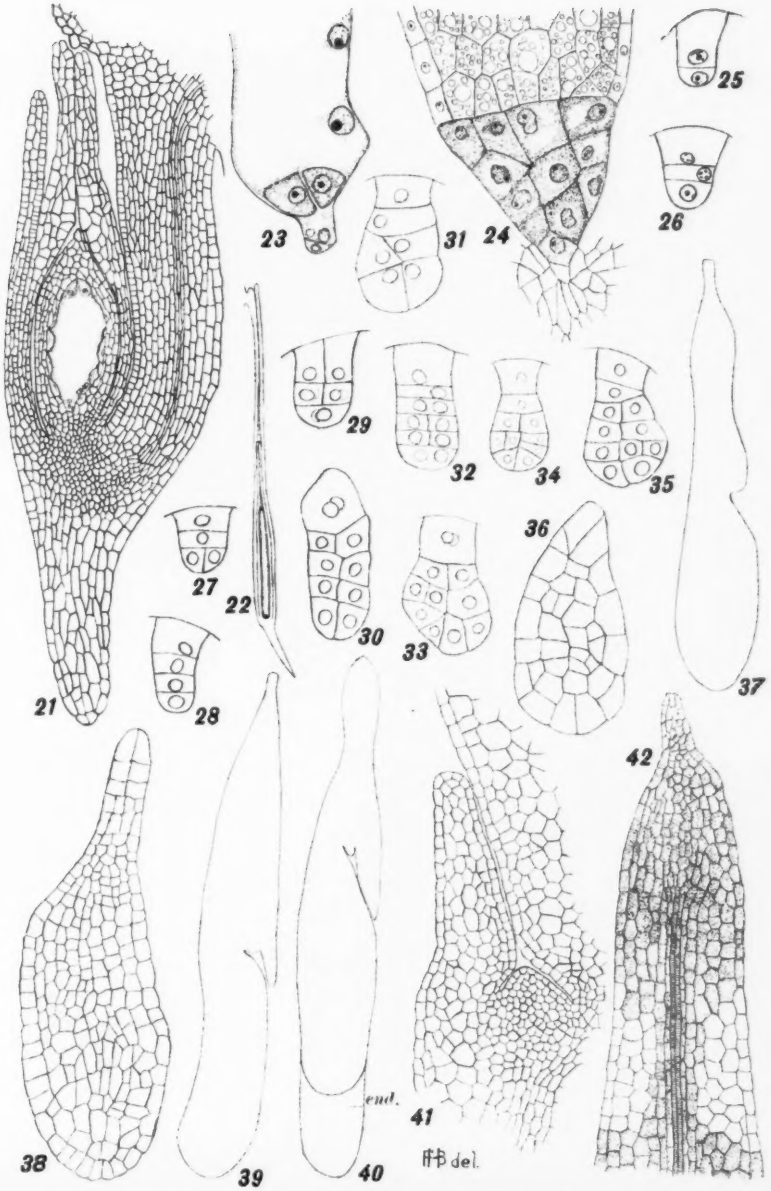
FIG. 23. First division in formation of chalazal endosperm tissue.

FIG. 24. Chalazal endosperm tissue and portion of endosperm that is to serve as reserve material in ripe seed.

FIGS. 25–26. Two- and three-celled embryos.



BILLINGS on TILLANDSIA.



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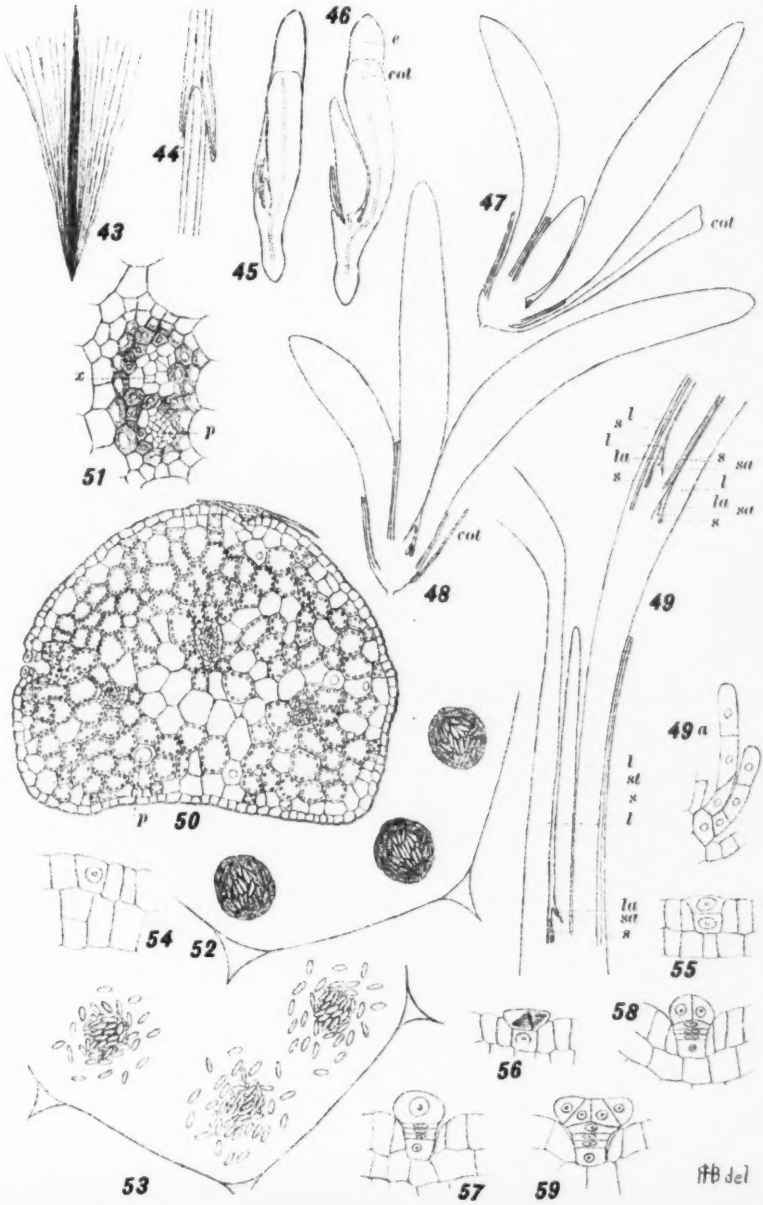

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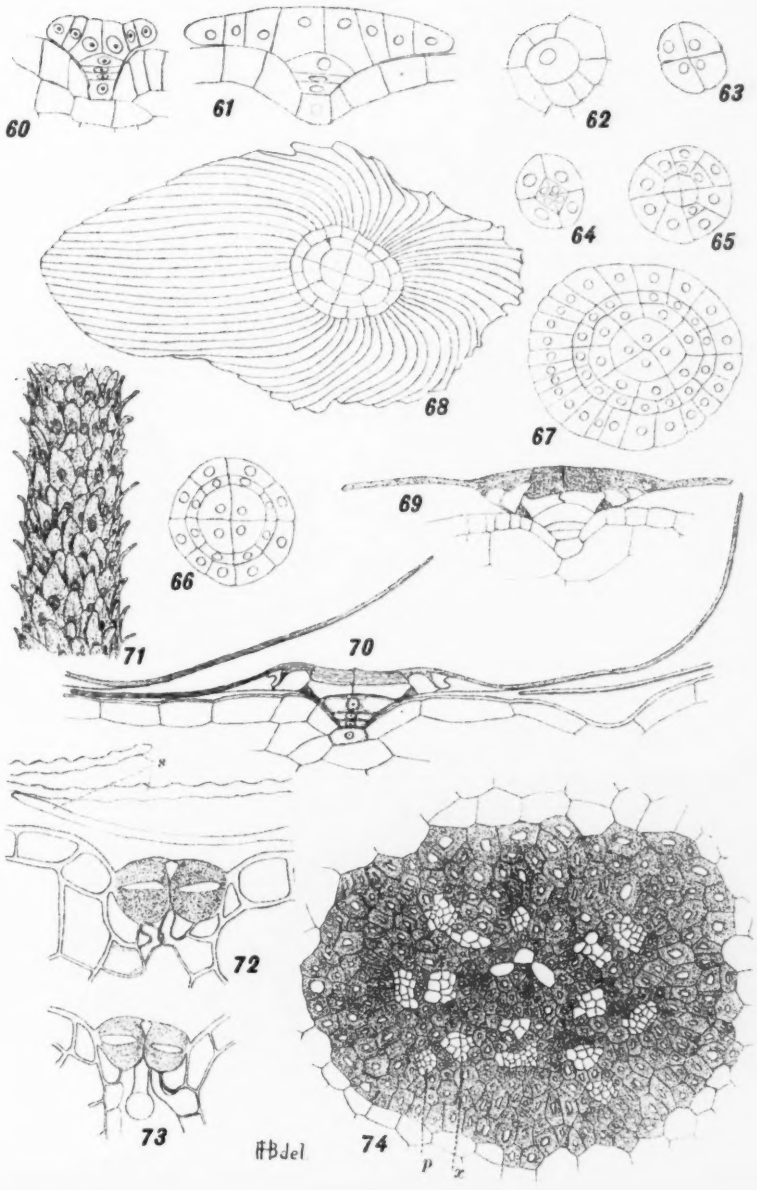

BILLINGS on TILLANDSIA.

FIG. 27. Formation of quadrant.

FIG. 28. Division of middle before terminal segment.

FIG. 29. Unusually early development of basal and middle segments.

FIG. 30. An unusual form of embryo.

FIGS. 31–36. Stages in embryo development; in *fig. 34*, the transverse walls in the terminal segment are oblique; the last three figures show beginning of dermatogen.

FIG. 37. Embryo about one-fourth grown.

FIGS. 38–40. Outlines of embryos in late stages of development; *fig. 30* represents a mature embryo.

FIG. 41. Region in vicinity of growing point of a nearly ripe embryo.

FIG. 42. Root region of nearly mature embryo, showing dead cortical cells.

FIG. 43. Ripe seed.

FIG. 44. Barbs on hair of coma.

FIG. 45. Early stage in germination; outline of longitudinal section.

FIGS. 46–48. Stages in development of seedling; outline of longitudinal section.

FIG. 49. Longitudinal section through the growing point regions of a mature plant: *s*, sheath; *st*, stem; *l*, leaf; *sa*, stem apex; *la*, leaf apex.

FIG. 49a. Very young sheath.

FIG. 50. Cross section of leaf; *p*, pit in water-storage cell.

FIG. 51. Bundle of leaf enlarged to show phloem (*p*) and xylem (*x*).

FIG. 52. Megachloroplasts showing division into microchloroplasts.

FIG. 53. Stage in separation of microchloroplasts by which they become distributed through the cytoplasm.

FIGS. 54–61. Stages in development of the scale seen in longitudinal section; *fig. 54* shows the epidermal cell from which the scale arises.

FIGS. 62–68. Stages in scale development seen from the surface; *fig. 68* shows a mature scale.

FIG. 69. Scale in longitudinal section, after soaking in water for several hours; the wing is seen to be raised considerably above the epidermis.

FIG. 70. Scale in longitudinal section, drawn from a paraffin section; it will be seen to lie much closer to the epidermis than the one in *fig. 69*.

FIG. 71. General appearance of the surface of the leaf, showing the scales.

FIG. 72. Section through a stoma; the guard cells are unquestionably closed; in addition a process has grown up from the parenchyma into the pore of the stoma; *s*, scales.

FIG. 73. Section of stoma showing slight variation from that in *fig. 72; figs. 72* and *73* were drawn from sections through living material.

FIG. 74. Cross section through the vascular region of the stem: *p*, phloem; *x*, xylem.

BIOLOGICAL RELATIONS OF CERTAIN DESERT SHRUBS.

I. THE CREOSOTE BUSH (COVILLEA TRIDENTATA) IN ITS RELATION TO WATER SUPPLY.

V. M. SPALDING.

(WITH SEVEN FIGURES)

THE general features of desert vegetation are well known and have been described in a voluminous literature. Certain striking peculiarities, such as the production of spines, development of tissue for water storage, and particularly the various anatomical means by which the loss of water is prevented or controlled, have received special attention, and still form the usual subject matter of observation and discussion.

These general and easily ascertained facts are by no means unimportant, and it is a decided advantage to botanical science that they have been recorded in such numbers. A far more important fact has become increasingly evident, namely that plants living together under present day desert conditions have each a history and character of its own, expressed in peculiarities of habits and physiological activities, and evidence is not wanting that, with changing and most complicated interrelations of organism and environment, through the long period in which each species has presumably been in the making, these peculiar habits and activities have been acquired.

But apart from all theoretical considerations, it is certain that a fairly intimate knowledge of even a limited number of desert species brings the conviction that no general statement is an adequate expression of the biological relations of any one of them, that each is a law to itself, and that its actual relations to the environment must be determined for each species by critical study of its own structural and physiological characteristics, one by one. It is from this point of view that the present study has been undertaken, and for this purpose certain desert shrubs have been chosen—the creosote bush, palo verde, and mesquite—all of which possess, each in its own way,

remarkable adaptations to desert conditions, and present striking examples of survival in a region that has passed from widely different conditions at an earlier geological period to its present extreme

FIG. 1.—*Covillea tridentata*, near Tucson, Arizona.—From Contrib. N. Y. Bot. Gard. No. 46. Plant World **6**: *pl. 35*.

aridity. Work on these several species is now under way at the Desert Laboratory of the Carnegie Institution, and as yet is incomplete. It is thought best, however, to embody in the form of a report

of progress the following notes on the creosote bush and its relations to water supply.

The creosote bush, *Covillea tridentata*, is, as is well known, one of the most characteristic species of the Lower Sonoran zone, and through its wide range, from California eastward to Colorado and Texas, and southward into Mexico, it is perhaps, of all the species of this zone, the one most constantly present and most firmly established (*fig. 1*). It occupies extended areas where its removal would leave a bare waste, but at the same time shares, on mesa and foot-hills, a great variety of soils and exposure with other species that exhibit far less capacity of accommodation than itself.

This power of accommodation is particularly noticeable as regards water supply. One has only to pass from the mesa east of Tucson, for example, to the low ground of the Rillito near Fort Lowell, observing the specimens of creosote bush as he goes along, to be convinced that the differences presented by them are due to the meager supply of water in the one case and its abundance in the other. More striking still are the changes that take place when individual plants are well watered. In contrast with the specimens around them to which no water is given, their leaves become deep green and undergo a marked increase in size, while the whole plant presents the appearance of robust health and remarkable vigor, very different from the pinched specimens with narrow, pale leaves, branches more or less defoliated, and other marks of a struggle that, however successful, is manifestly one of great severity. Plants that have been well watered for a period of years are far more fruitful than their companions standing in dry ground near by, and from their vigor, fruitfulness, and habit of retaining a greater number of healthy leaves and branches, there can be no question as to which is the normal condition; the creosote bush reaches its normal development where there is a full supply of water; arid conditions are indeed tolerated to a remarkable degree, but the plant is dwarfed and suffers in other ways while it endures them (*fig. 2*).

These facts, though matters of every day observation, are highly significant. Provisionally they may be interpreted as indicating that the creosote bush, living over much of the territory where it is now found from the period of maximum precipitation to the present time,

has acquired habits that enable it to withstand excessive drouth, but has never lost its capacity to absorb and use large quantities of water, and attains its best development only under such conditions.

The readiness with which this species accommodates itself to an over-supply of water is shown by a simple experiment. Seedlings of Covillea were grown in a flower pot, and after they had made a

FIG. 2.—Branches of Covillea; on the right from a well watered bush near St Mary's Sanatorium, north of the Desert Laboratory; on the left from the exceedingly dry soil of the mesa close by.

good start were set into a can of water, the bottom of the pot having been broken through in several places. After three or four weeks it was found that some of the roots had grown down into the water and, in contrast with those growing in the soil, had taken the form of water roots, being entirely destitute of root-hairs. The epidermal cells exhibited plasmolysis with a 4 per cent. solution of potassic nitrate, thus indicating their capacity for active absorption. Seedlings grown in the Geneva tester also sent their primary roots down into the water without apparent injury. It is plain, then, that the roots of

Covillea are capable of growing in water, at least for a time, and carrying on normal absorption there.

In order to observe the effects of too great and too small a supply of water on plants growing in soil, seeds were sown in two receptacles measuring 23^{cm} in depth, and were treated as nearly alike as possible except as to the amount of water given to them. Both stood where they received sunlight through a wire screen during the entire day. One lot received a very large amount of water, manifestly much more than they required, and the other lot was given very little, so little that at times they seemed in danger of drying up. At such times they were given a little more water, after which it was withheld again.

All the plants flourished, but in the course of a few weeks there was a marked difference between those that had received an excessive supply and the ones that had received a meager supply of water. April 12th, eight weeks after the seeds were sown, the plants were carefully washed and examined. The seedlings of both lots presented a fine, healthy appearance, and the roots of both had reached the bottom of the receptacle in which they were growing and had spread out upon it. They differed most conspicuously in the development of stems and leaves (*fig.* 3). Those that had received an excessive amount of water measured approximately 2^{cm} more in height than those to which a meager supply had been given, and the leaves were both larger and more numerous, numbering from 6 to 10 in representative specimens of the former as against 4 to 8 in the latter; while the largest leaflets in the two lots measured respectively 1.4 and 0.8^{cm} in length. Neither lot showed as strong a development of the root system as plants grown under the same conditions to which an abundant, but not maximum, supply of water had been given. Microscopic examination showed that while both lots were characterized by abundance of root-hairs, these were most numerous and better developed on the roots that had received little water.

It will be instructive to compare with this the record of two other lots of seedlings that had been under observation for a period of seven weeks, during which one lot had been given an oversupply of water, while the other received very little. On March 31st, when they were taken up and washed free from the soil in which they had grown, it was found that the plants to which little water had been given had

a strong and well-developed root system, but that this was very poorly developed in those that had received much water. It was noticeable, too, that while the latter were not altogether destitute of root-hairs, they had not produced them in anything like the abundance characterizing those that had been given little water, there being long stretches on which no root-hairs whatever were to be seen. Both lots of root-hairs showed plasmolysis of epidermal cells near the tip of the fresh root, and of the adjacent root-hairs, with 3 per cent. solution of potassic nitrate, but farther back in both cases plasmolysis was effected with difficulty or not at all. As for the parts above ground, both lots of seedlings had grown well, but those that had been given too much water were of a decidedly lighter green, approaching a sickly color.

From these and other observations it appears that when given an excessive quantity of water seedlings of Covillea make a remarkably rapid growth above ground, but produce a less number of root-hairs than those that have a meager supply, besides show-

FIG. 3.—Seedlings of Covillea eight weeks old, showing effect of excessive and meager water supply.

ing other differences that may be passed over at present. The capital fact, however, is that this species, whether as seedling or mature plant, exhibits an endurance of extremes in the matter of water supply that apparently very few species not possessing a storage system or its equivalent have attained.

This ready adjustment to differences of water supply, manifested not only in power of endurance but also in rate of growth and in other particulars, might naturally be expected to find expression in a corresponding varying rate of transpiration; it becomes, therefore, a matter of special interest to determine the habits of the creosote bush in this respect, particularly after long periods of drouth. Accordingly a series of experiments were conducted in which the hygrometric method of determining transpiration, suggested by Dr. D. T. MACDOUGAL was chiefly employed.[1] By permission of the Desert Laboratory some of the results are here given in advance of publication elsewhere, in which a full account of methods employed by Dr. W. A. CANNON will be given by him.

At the time these experiments were undertaken, late in April, extremely dry conditions, both of atmosphere and soil, had long prevailed. The rainfall since September 1903, a period of nearly seven months, had aggregated only one inch, spring flowers had failed to appear, and during nearly all of the winter and spring an intolerable dust had filled the roads and risen into the air. Under such circumstances it might naturally be expected that transpiration on the part of every plant not artificially watered would be reduced to a minimum; the facts of the case, however, by no means warrant this conclusion.

Two specimens of Covillea were selected, one on the hill a little to the northward of the laboratory, the other at the foot of the hill in the same direction. The former presented the fresh appearance exhibited by most of the creosote bushes near the laboratory, indicative of a water supply, however limited, in excess of that in the plain below, where the bushes looked dull and dried-up, as if subjected to most severe conditions, to which it seemed as if they must succumb.

[1] This consists essentially in direct reading of a specially constructed hygrometer placed with the plant under a bell-jar, from which escape of moisture is prevented by oiled silk or a cement base. The correction for vapor-pressure is made once for all by weighing calcium chlorid before and after the saturated air of the bell-jar has been passed through it.

TRANSPIRATION OF THE CREOSOTE BUSH.

No. 1. April 22, 1904.

Time A. M.	Percentage of saturation	Temperature	Amount in milligrams
10:51	17	26° C.	105
10:54	19.5	27	121
10:56	22	27.5	149
10:58	25.5	28	177
11:00	29.5	28	198
11:02	35.5	28.5	256
11:04	40.5	29	300
11:06	48	29	355
11:08	54	29	398
11:10	60	29	444
11:12	64	29.5	487
11:14	67.5	29.5	514
11:16	70	29.5	532
11:18	72	29.5	548
11:20	74	29.5	564
11:22	75	30	582

No. 2. April 23, 1904.

Time A. M.	Percentage of saturation	Temperature	Amount in milligrams
8:57	21	24.5° C.	62
9:03	22.5	25.5	69
9:08	23.5	25.5	72
9:13	24.5	26	76
9:18	26.5	26	84
9:23	29	26	91
9:28	32	26.5	104
9:33	35.5	26.5	116
9:38	39.5	27	132
9:43	42.5	27	142
9:48	46.5	27.5	152
9:53	47.5	27.5	165
9:58	49	28	173
10:03	50	28	178
10:08	49.5	28.5	183

The above table gives in milligrams the aggregate amounts of watery vapor transpired during the indicated periods by each of the plants under observation, and the amounts given off are represented graphically by the accompanying curves (*fig. 4*). The

readings of the hygrometer were reduced by means of the Smithsonian meteorological tables and the appropriate correction then applied for the bell-jar employed. Later experiments indicate that the correction applied in the present case must be considered approximately rather than quantitatively exact, but this does not affect the value of the comparisons that follow.

From the tables here given it is seen that for the time of observation the rate of transpiration of the two plants respectively was: no. 1, 924^{mg} per hour; no. 2, 102^{mg} per hour.

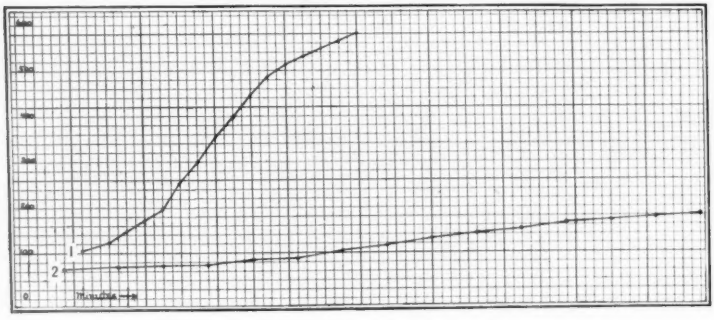

FIG. 4.—Curves showing rate of transpiration of two creosote bushes and amount transpired by no. 1 in 31 minutes and by no. 2 in 1 hour and 11 minutes.

By counting the leaves of each plant and estimating their surface and that of the green shoots on which they were borne, the entire transpiring surface was estimated as: no. 1, 1533$^{sq\,cm}$; no. 2, 660$^{sq\,cm}$.

For equivalent surfaces, therefore, the rate of transpiration of no. 1, the plant on the hill, was 3.7 times that of no. 2, the plant on the plain below. Further experiments gave similar results. A branch of a creosote bush growing where the ground had been thoroughly soaked a few weeks before by the running over of water from the tank of the Desert Laboratory was exceptionally fresh and green, and its rate of transpiration, for equivalent surfaces, was found to be 8.9 times as great as that of the bush on the mesa.

From these and other detailed experiments not here reported, it is abundantly proven that after months of excessive drouth the

creosote bush on the mesa and foot-hills is still transpiring considerable quantities of water. The amount transpired appears to stand in direct relation to the amount of water available in the soil where the plant is growing, as is indicated by the following comparison of percentages of moisture given off by the soil when air dried.

Samples of soil were taken at depths of 20 to 30^{cm} below the surface from points near the plants on which the transpiration experiments were conducted. In each case the sample was weighed, then left in a shallow basin in the air, exposed to sunlight, but protected from draughts of wind, for three days, after which the weighing was repeated. It was found that the soil from the laboratory hill, taken at a depth of 30^{cm} below the surface, lost by air-drying during this period 8 per cent. of its weight, while that from the plain near the foot of the hill, which was much drier and in which the creosote bushes were evidently suffering from lack of water, taken from a depth of 20 to 25^{cm}, lost at the same time 3 per cent. Another sample from the hill lost by heating over an electric stove 12 per cent. of its weight. The days when the drying was done the relative humidity of the atmosphere ranged from 20 to 27 per cent.

It is of course essential that much more extended and critical work in this direction should be carried out. Meantime the important fact is established that after months of excessive drouth the soil in which creosote bushes were living, taken only a few inches below the surface, gave up when air dried 3 to 8 per cent. of its weight of watery vapor, while a considerably higher per cent. was driven off by heat. This fact being proven, our interest chiefly centers in the capacity of the plant to utilize the available soil water after it has been so greatly reduced. This involves a study of the root system.

By way of ascertaining first general facts, the roots of creosote bushes were examined by carefully removing the earth in which they were growing, and then following their ramifications as far as possible. This is not an entirely satisfactory procedure, inasmuch as it is quite impracticable to follow the finest roots to the end without breaking them off. It is possible, however, to lay bare so large a part of the root system as to obtain a clear view of its direction of growth, mode of branching, and other characteristic features. *Fig. 5* is a photograph of two seedlings of Covillea, a few months old, that

were taken up from the mesa east of Tucson, January 13, 1904. The soil where they were dug, though rather light, is relatively deep, and it is noticeable that while the lateral roots had attained only a slight development, the tap-root had reached a depth of over 31 cm in the one case, and upwards of 53 cm in the other. A much older plant, taken up from the plain northward of the Desert Laboratory, where the soil is underlaid by rock, shows a strong development of secondary roots, and the tap-root, instead of continuing vertically downward, turns off at a small angle from the horizontal, but finally, at 80 cm distance from the main axis, turns directly downward. The lateral roots in their turn continue near the surface only a short distance, and then, in spite of the rocky nature of the substratum, turn downwards, reaching 40 to 45 cm in depth where they were broken off, though probably extending to a considerably greater depth (*fig. 6*).

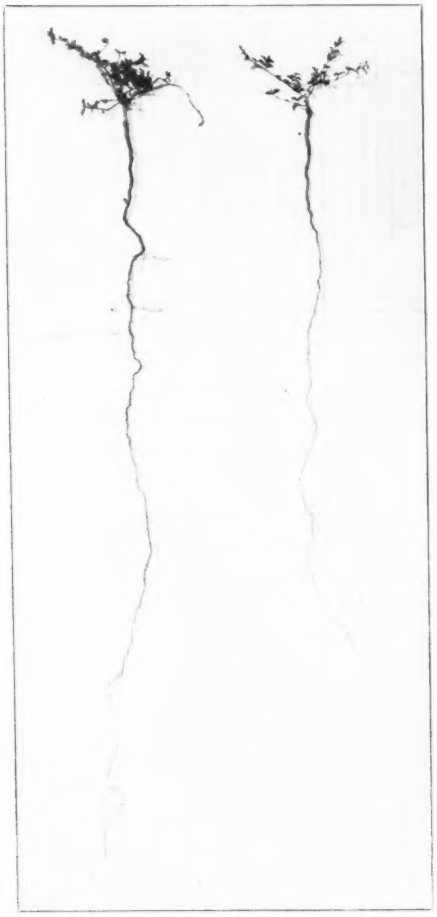

FIG. 5.—Seedlings of Covillea from the mesa east of Tucson, Arizona.

The position of this particular plant with respect to those around it is instructive, and may account in part for the distribution of its

roots. Compare the diagram, *fig. 7*, showing the position and distance of a Parkinsonia, Fouquieria, Opuntia, and another Covillea. The roots were traced more than half the distance to the Parkinsonia in one direction, and to the Fouquieria in the other.

FIG. 6.—Covillea from plain to the north of the Desert Laboratory, showing character of root system.

From these and many other individual plants that have been examined, it has been found that the general plan of the root system is essentially the same in all; there is a strong tap-root which grows downwards until it meets an obstruction, or for some other reason changes its course, and slender lateral roots which run near the sur-

face for some distance. It has not thus far been practicable to ascertain the extreme distance to which either the main or lateral roots may extend. At the entrance of an abandoned mine the roots of a rather small plant were found exposed at a depth of 3^{m}, and from their size at this point, it is probable that they extended 1.5^{m} or more farther. Larger specimens doubtless send their roots to much greater distances. In any case it is seen that the root system spreads widely and penetrates deeply into the earth, a disposition well adapted to secure what water is available through a comparatively wide area when there is a light rain, while the longer divisions of the root extend to the water brought by heavier rains that have reached lower levels. Such an arrangement is all the more advantageous in view of the lack of a special storage system, the root as a whole being manifestly incapable of holding any considerable quantity of water.

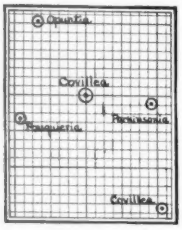

FIG. 7.—Position of Covillea with reference to plants around it, on plain north of Desert Laboratory.

The development of the root has been followed for some months by observation of seedlings grown in flower pots and larger receptacles. Some of the results have been referred to already in the discussion of growth of seedlings as affected by water supply. There are other facts, however, particularly the behavior of root-hairs and their relation to absorption, that require separate consideration.

Seeds germinated in a Geneva tester, so that the radicles grew in moist air, gave opportunity to observe the early formation of root-hairs under these special conditions. As was to be expected from what has been observed in other species, they were developed in the damp air of the tester while the radicles were still very short, there being in some instances numerous root-hairs before the radicle had reached a length of 3^{mm}. In other cases it had grown to the length of 1^{cm}, more or less, before any were produced. In some cases they were close to the root tip, in others farther back, all on one side of the radicle, or projecting from all sides; in short here, where conditions were far more nearly uniform than often happens, there was such variety of habit as to render it extremely difficult to ascertain the factors actually determining the outgrowth of epidermal cells into root-hairs.

Much the same difficulty was experienced with seedlings grown in soil. In some cases the root-hairs arise thickly in complete zones, the rest of the root being free from them; in other cases, while they are abundantly produced, their distribution is extremely irregular; and in still other specimens of the same lot of seedlings the root is nearly naked, there being almost no root-hairs whatever.

In examining a large number of seedlings grown under different conditions other possibly important data in regard to this matter have been obtained, but for our present purpose it is sufficient to emphasize the well established fact that the roots of Covillea, whether growing in the lighter soil of the mesa or the heavier soil of the laboratory hill, ordinarily produce great numbers of root-hairs, and that their number becomes less if the plant is given a very large quantity of water. If grown directly in water root-hairs are altogether wanting. Whatever other conditions, then, may or may not afford the stimulus that results in the production of root-hairs in general, the quantity of water in the soil is, in the present case, a factor of prime importance. There is no doubt that the epidermal cells of the root of Covillea which would retain their original form if abundantly supplied with water do, as a matter of fact, promptly increase their surface greatly by pushing out root-hairs if the water supply is suitably diminished. Whether in this process the epidermal cell responds directly to the diminished supply of water in the soil around it, or to conditions arising from lack of water in the plant of which it is a part, is a question of theoretical interest well worthy of special investigation.

The epidermal cells near the tip of the root, whether prolonged into root-hairs or not, function as the living agents of absorption. To what extent the older root-hairs may function in the same way, or may serve rather to soak up water like a sponge, when there is an abundant supply, is a question reserved for fuller discussion than can be entered into here. We are now concerned, first of all, with the degree of force with which the undoubtedly vital agents of absorption, the living cells near the root-tip, absorb water from the relatively dry soil in which, as we have seen, the creosote bush maintains itself alive and keeps up its transpiration "stream."

In the investigation of this subject, which is still in progress, seedlings of Covillea, of different ages were carefully removed from the

soil and subjected to the action of plasmolyzing agents. A few of the experiments undertaken will be given in detail.

A young seedling, with a slender primary root 2^{cm} long, showed distinct plasmolysis of the epidermal cells near the root-tip within five minutes after being placed in 3 per cent. solution of potassic nitrate, and the same phenomenon was soon after obtained as far back as 1.6^{cm} from the end of the root. Some of the root-hairs also showed plasmolysis, but not so strongly as the epidermal cells. In the latter it was particularly distinct.

At the same time a number of good specimens growing in the Geneva tester were treated on separate slides with 2, 3, 4, and 5 per cent. solutions of KNO_3 at a temperature of 27° C. With the 2 per cent. solution plasmolysis was not observed; with 3 per cent. it was seen doubtfully or incompletely in a few of the epidermal cells; with 4 per cent. plasmolysis in many epidermal cells was strongly marked; and with 5 per cent. not only was plasmolysis promptly and strongly induced in the epidermal cells but also in some of the root-hairs. It is seen from this experiment, and from others not reported, that the root-hairs plasmolyze less readily than the neighboring epidermal cells. In the present case, while the application of 5 per cent. solution of KNO_3 was promptly followed by plasmolysis of some of the root-hairs, others failed altogether to exhibit the phenomenon.

Similar results were obtained from a lot of seedlings raised in soil in flower pots. They were strong and healthy, and at the end of five weeks' growth, when they were taken up for experimentation, some of them had one or two leaves well developed Employing the secondary roots of one of the best developed individuals it was found that plasmolysis did not occur in 3 per cent. solution of potassic nitrate; that it took place promptly and distinctly in 5 per cent., both in epidermal cells and root-hairs; and that in 4 per cent. different specimens exhibited a marked difference of behavior. Of five specimens placed in 4 per cent. solution two showed plasmolysis satisfactorily, both of the epidermal cells and root-hairs, while two failed to do so, and one showed plasmolysis well in the epidermal cells but not in the root-hairs.

In these, as generally in roots subsequently examined, it was found that the older root-hairs, farther back from the tip of the root,

are very slow to become plasmolyzed, or for the most part fail altogether, in solutions that readily induce plasmolysis of fresh young cells and root-hairs near the tip. It was found, however, that some of the older root-hairs that are not too far back from the tip exhibited plasmolysis distinctly in a 10 per cent. solution of KNO_3, but the great majority are not affected by this nor by higher percentages.

In the course of the work it was repeatedly noticed that many of the older root-hairs presented the appearance of having undergone regeneration, the distal end being clear or semitransparent, in contrast with the dark-colored basal part with its old-looking granular contents, the clear terminal portion being irregular in outline and not infrequently branched. In the course of experiments on an herbaceous plant, *Verbena ciliata*, which showed the same phenomenon even more strikingly than did the creosote bush, it was found that regeneration of its root-hairs could be induced readily by supplying with water a plant from which it had been withheld for some time. It is probable that this capacity for renewed growth on the part of cells apparently dormant may be an important factor in the absorption of water from the soil.

To sum up briefly the observed facts regarding the absorbing cells of the roots of Covillea: Root-hairs are, as a rule, produced in large numbers, thus increasing many times the absorbing surface. If the plant receives large quantities of water the number of root-hairs falls off, and when the roots grow in water none are produced, the creosote bush agreeing in this respect with what has been observed in land plants generally. The undoubtedly active absorbing tissue consists of epidermal cells and root-hairs very near the growing point of both primary and secondary roots. These cells fail to show plasmolysis with less than 3 per cent. solution of KNO_3 and are readily plasmolyzed with higher percentages; their osmotic pressure may accordingly be set down, with more or less variation, as equivalent to ten atmospheres.

The behavior of older epidermal cells and root-hairs is such as to throw doubt upon their functional activity as absorbing cells, though from their observed habit of regeneration under certain circumstances, and from their action with plasmolyzing agents, there are

grounds for assuming provisionally that a considerable proportion of these are still capable of serving this purpose. If they are thus active, their osmotic force, as measured by plasmolysis, is several times that of the younger cells nearer the root-tip. It is apparent, in any case, that the osmotic force exhibited by the root-hairs and epidermal cells that are indubitably active is amply sufficient to account for the capacity of this plant to absorb water from the soils in the vicinity of the Desert Laboratory, even after such periods of drouth as those of the present year. Their absorption, however, is necessarily limited by the amount of water available. This, as we have seen, is also a determining factor of transpiration. The means by which the latter is controlled will be discussed elsewhere.

That the creosote bush is able, through its absorbing cells, to abstract continuously a certain amount of water, however small, from such dry soil as that of the desert mesa, to maintain transpiration through many months of excessive drouth, and at the same time to regulate nicely the amount of transpiration to correspond with available water supply, while all the time it is capable of living and does live as an ordinary mesophyte when given a suitable supply of water, is a remarkable fact. Its explanation involves more perfect knowledge not only of the physiological habits now under investigation, but also of the geographical history of the species, which still remains to be written. It need hardly be said that the data for both are to be sought first of all in the desert where this plant is at home.

I desire to express my sincere thanks to Dr. W. A. Cannon, the resident investigator of the Desert Laboratory, and to Messrs. Coville and MacDougal of the Advisory Board for the admirable facilities that have freely been placed at my disposal.

DESERT BOTANICAL LABORATORY,
Tucson, Arizona.

BRIEFER ARTICLES.

NOTES ON NORTH AMERICAN GRASSES. III.

AGROSTIS STOLONIFERA L.

In view of the recent tendencies to base species so far as possible upon type specimens, or in the absence of such specimens upon a definite idea to be interpreted from references to the older authors, it becomes necessary to investigate carefully the bases upon which are founded the Linnaean binomials. Two species of Agrostis are here considered.

A. stolonifera was described in the first edition of Linnaeus's *Species Plantarum* as follows (p. 62, under the second division, MUTICAE):

stolonifera. 7. Agrostis paniculae ramulis divaricatis muticis, culmo repente, calycibus aequalibus.

Agrostis culmo repente foliis radicalibus breviore, folii suprema vagina ventricosa, flosculis muticis. Roy. ludgb. 59. Fl. suec. 62 (61).

Agrostis culmo repente vagina supremi folii ventricosa. Roy. ludgb. 59. Dalib. paris. 23.

Gramen caninum supinum minus. Scheuch. gram. 128. Habitat in Europa. ♃

There are three factors which enter into the determination of the type of a species: the specimen or specimens from which the description was drawn, the synonyms and citations given in the original description, and the description itself. Establishing types for Linnaean species is complicated from the fact that the descriptions may be not original with Linnaeus. His work has been that of an editor who has taken material at hand and rearranged it in accordance with his system of binomial nomenclature. Frequently he merely attached a trivial or specific name to species already well known under a polynomial designation. The older authors were not accustomed to give citations of definite specimens or definite localities. Let us examine in detail the data for determining the type of *Agrostis stolonifera*.

1. *The specimens.*—In the Linnaean herbarium (in the rooms of the Linnaean Society of London) there is only one specimen labeled with this name. This is from "Attica" and is marked in the handwriting of Linnaeus himself. This specimen is what has been going under the name of *A. ver-*

ticillata Vill. The species is common in southern Europe, but is not found in England or the Scandinavian countries. I found no other specimen labeled *A. stolonifera*, although Munro states that there was also one marked thus which was a form of *A. alba* (Proc. Linn. Soc. London, Bot. **6**: 40. "The Herbarium contains one of the forms of *A. vulgaris*, which is called *stolonifera*, the Fiorin Grass; another, marked *stolonifera*, by Linn., is *A. verticillata* Vill.").

2. *Synonyms and citations.*—The first synonym is from Linnaeus's *Flora Suecica*, p. 23, no. 61 (1745). The citation is as quoted, but lacks the words "flosculis muticis." The description agrees with *A. verticillata* Vill., especially "folii supremi vagina ventricosa." To the description in this work is added:

> Gramen caninum supinum minus. Scheuch. hist. 128.
> Agrostis stolonifera vulgo.
> Suecis Kryp-hwen.
> Habitat in agris incultis ubique praefertim Upsaliae.

The reference here to Scheuchzer is the same as given in the *Species Plantarum*. The description in Scheuchzer's *Agrostographia* is quite full and agrees well with *A. verticillata* Vill. Scheuchzer gives references to Bauhin, but the descriptions of the latter author are less satisfactory.

It is to be noted that the first citation given by Linnaeus (*Sp. Pl.*) is "Roy. lugdb. 59." This is an error, as this does not appear in Royen, *Flora Leydensis*, the work referred to.

The second citation (L., *Sp. Pl.*) is correctly quoted from Royen. This is also referred to "Dalib. paris. 23." This is also an error, as the first citation appears here. It appears then that the authorities "Roy. lugdb. 59" under the first citation, and "Dalib. paris. 23" under the second citation should be interchanged. As the description in Dalibard, *Flora Parisiensis*, quotes Linn. *Fl. Suec.* 61, this still leaves the *Flora of Sweden* as the basis of the first synonym. It may be remarked that Dalibard also quotes the description from Royen and "Gramen caninum supinum minus." Royen quotes a polynomial from Ray's *Synopsis* which refers to an Irish plant, probably some form of *A. alba*.

Going back to the *Flora of Sweden*, we find as the first synonym the citation from "Scheuch. hist. 128," which is *A. verticillata* Vill.

All the evidence under the head of synonymy, then, is in favor of *A. verticillata* Vill. as being the basis of Linnaeus's *A. stolonifera*, except that the description appears in a *Flora of Sweden*, where *A. verticillata* does not occur, or at least not commonly, and yet is said to be common there in uncultivated fields. Linnaeus evidently had confused two species—what we have

been calling *A. alba* and *A. verticillata*. It would seem best to dispose of this conflict by admitting that Linnaeus committed an error of determination in identifying the Swedish plant with the form common in southern Europe.

In this connection it is interesting to note that Linnaeus has little to say about *A. alba* in the *Species Plantarum*. The description is:

> 9. Agrostis panicula laxa, calycibus muticis aequalibus. Roy. lugdb. 59. Habitat in Europae nemoribus.

Royen adds as a synonym "Gramen nemorosum, paniculis albis. Vaill. par. Tab. 17. f. 5. opt."

The figure in Vaillant, however, is not an Agrostis, but apparently a species of Poa.

There are several sheets of *A. alba* in the Linnaean herbarium, one of which is marked in his own handwriting and is the common form of what has been so called.

3. *Description.*—The part relating to the divaricate panicle refers better to *A. alba*, especially the variety *vulgaris*, but the part relating to the creeping culm and the equal calyx refers better to A. *verticillata*.

Taking everything into consideration, it appears that Linnaeus confused two species, but we are justified in taking the specimen in the Linnaean herbarium as the type of *Agrostis stolonifera* L. = *A. verticillata* Vill.

The identity of the Linnaean specimen has been pointed out by earlier authors, *e. g.*, Parlatore *Fl. Ital.* 1: 180.

AGROSTIS RUBRA L.

The description given in the *Species Plantarum* (p. 62) is:

> *rubra*. 4. Agrostis paniculae parte florente patentissima, petalo exteriore glabro terminato arista tortili recurva. Fl. suec. 60. Dalib. paris. 24.
>
> Agrostis panicula inferiore verticillatim laxa; superiore contracta. Fl. lapp. 46.
>
> Gramen serotinum arvense, panicula contracta pyramidali. Scheuch. gram. 148.
>
> Habitat in Europae arenosis subhumidis.

1. *Specimens.*—In the Linnaean herbarium there is one sheet marked by Linnaeus, but the plant is a panicle of what appears to be *Sporobolus junceus* of our southern states. As this does not accord with the description or citations, it may be withdrawn from consideration, as there is evidently an error somewhere.

2. *Synonymy.*—In the *Flora Suecica* the three citations appear as given in the *Species Plantarum*, and in the same order, but "Dalib. paris. 24" is omitted, as this is a subsequent work (1747). There is added, however:

Gramen serotinum arvense, spica laxa pyramidali. Raj. hist. 1288. Vaill. paris. 88.

Suecis Röd-hwen.

Habitat ad ripas lacuum & in partis depressis ubique.

In the *Flora Lapponica*. p. 27, no. 46 (1737) we find in addition to the quotation given above (in which *inferne* replaces *inferiore*):

Gramen segetum arvense, panicula contracta pyramidali. Raj. hist. 1288. Scheuch. hist. 148.

α Ad ripas lacuum, tempore autumnali; rufescens occurrit.

β Panicula, dum floret, secundum verticillos explicatur horizontaliter patens; contracta superius in eadem nondum florente.

The references to Ray and Scheuchzer are based on *Milium lendigerum*, as are also those of Vaillant and two additional references which he gives. "Plukenet Phytographia Tab. 33, fig. 6," and "Tournefort Institutiones Rei Herbariae 515."

3. *Description.*—There is no description in the *Species Plantarum* aside from the synonyms given, but the habitat "in arenosis subhumidis" would not seem to apply to the plant going under the name of *A. rubra* L. = *A. borealis* Hartm., which is an alpine grass.

The description given in the first citation, "Fl. Suec.," does not apply to *A. borealis* Hartm., as the flowering glume ("petalo exteriore") is said to terminate in a recurved twisted awn. The awn in *A. borealis* arises from the back of the glume. It is to be noted that Linnaeus described the next species, *A. canina*, as having the awn dorsal (Sp. Pl. 62; Fl. Suec. 392, no. 1138). As the awn is terminal in *Milium lendigerum*, it is probable that this part of the description was based upon that species, which he has in some way confused with the Swedish plant. It is also to be noted that he describes in his *Flora of Lapland* only two species of Agrostis, *A. capillaris* and the species under consideration. It has been pointed out by several European authors that Linnaeus evidently confused two or more species under *A. rubra*, one of which was *A. vulgaris*. This, added to his error of determination in identifying the Scandinavian plant with *Milium lendigerum* of southern Europe and the consequent mixing of synonyms, has made it impossible to determine with any definiteness the type of *A. rubra*. For this reason it is best to take up the next available name, *A. borealis* Hartm. Skand. Fl. Ed. 4. 23. 1843.

Linnaeus evidently discovered his error in regard to *Milium lendigerum*, for in the second edition of the *Species Plantarum* he described this and based the name on "Raj. Hist. 1288, Scheuch. Gram. 148." He also

cites "Pluk. Tab. 33 fig. 6," but forgets to withdraw this citation from his synonymy under *A. rubra*.—A. S. HITCHCOCK, *U. S. Department of Agriculture.*

CARL SCHUMANN.

A BIOGRAPHICAL SKETCH [1] (WITH PORTRAIT).

KARL MORITZ SCHUMANN was born June 17, 1851, in Görlitz (Silesia). After attending the Real-Gymnasium of his native town until 1869, he studied at the universities of Berlin, Munich, and Breslau, devoting himself at first to chemistry, later principally to botany and related sciences. The doctor's degree was conferred upon him by the University of Breslau, July 19, 1873, the title of his dissertation being *Dickenwachsthum und Cambium.*

A year previously he had accepted a position as assistant to Professor Dr. GOEPPERT, the famous authority on fossil plants, which he held until the spring of 1876. In November 1875 he passed with honor the Prussian state examination, and shortly afterwards took up the profession of teaching. For eight years, beginning with 1876, he taught in the Real-Gymnasium "Zum heiligen Geist" in Breslau. A work entitled *Kritische Untersuchung über die Zimmtländer*, which he wrote during this time, showed as much historical and geographical as scientific knowledge. On account of this book he was called in the summer of 1884 to Berlin, where he was appointed curator of the Berlin Botanical Museum recently established by A. W. EICHLER. In June 1892 he was appointed professor, and in the spring of 1893 he obtained the right to deliver academic lectures on botany in the University of Berlin. On March 22, 1904, death closed his full and fertile life.

The contributions by which SCHUMANN advanced scientific botany are extraordinarily numerous, and as the work of a single man most astonishing. We may divide them into purely systematic, phytogeographic, morphological, biological, pharmaceutical, didactical, biographical, and the work of reviewing.

[1] Excerpt from a manuscript of Professor Volkens.

In MARTIUS's *Flora Brasiliensis* he worked up Triuridaceae, Cactaceae, Sterculiaceae, Tiliaceae, Malvaceae, Bombacaceae, Bignoniaceae, and Rubiaceae; and for ENGLER and PRANTL'S *Die natürlichen Pflanzenfamilien*, in addition to the above mentioned families, he treated Chlaenaceae, Elaeocarpaceae, Asclepiadaceae, and Apocynaceae. Of monographs there exist from his pen Marantaceae, Musaceae, and Zingiberaceae in ENGLER'S *Pflanzenreich;* and Sterculiaceae in ENGLER'S *Monographien ausgewählter afrikanischer Pflanzenfamilien*. As an independent work he published the *Gesamtbeschreibung des Cacteen* and *Iconographia Cactacearum*. The new species he described may be numbered by hundreds, probably by thousands, especially notable among them being those of tropical Africa. For the most part they were published in ENGLER'S *Botanische Jahrbücher*.

Among the phytogeographic works of SCHUMANN are *Flora von Kaiser-Wilhelmsland*, in which he was assisted by LAUTERBACH; *Flora von Neu-Pommern;* and *Flora der deutschen Schutzgebiete*. Of his biological and didactical treatises the most important are his investigations on myrmecophilous plants, and two text-books on systematic botany, *Lehrbuch der systematischen Botanik* and *Prakticum für morphologische und systematische Botanik*, the latter appearing after his death. Among his pharmaceutical contributions are the new edition of BERG and SCHMIDT'S *Atlas der officinellen Pflanzen*, observations on Hydrastis and Podophyllum, and several articles on plants yielding caoutchouc and kola. Among his biographical works are numerous necrologies of well-known botanists; and his editorship of JUST'S *Jahrbuch* must not be forgotten.

The starting-point of SCHUMANN'S morphological investigations was his studies on the development of the organs of flowers. These interested him most deeply and allowed him to show in a striking manner his masterly descriptive powers. On observations of this kind were based his papers on the borragoid, on the monochasia, on the ramification of Pandanus; as well as his studies in regard to the morphology of flowers, the results of which he published in his voluminous work *Ueber den Blütenanschluss*. SCHUMANN was the first to point out the untenableness of the prevailing theory of the purely formal morphology of flowers. He showed that mere comparison and the consideration of teratological facts lead to the most erroneous ideas, if it is desired to account for the position of the organs in their causal connection. The only way to advance the science of the morphology of flowers, he claimed, is to apply the principles which SCHWENDENER had employed in his mechanical theory of the position of the leaves in relation to the vegetative organs. It must not be concealed that SCHU-

MANN later, in his *Morphological Studies*, I and II, did not strictly adhere to this view, and that he even began to doubt the basis of the mechanical theory of leaf position. To him, however, belongs the honor of having immensely advanced botanical morphology by means of a wealth of single observations, at a period when this branch of science elicited nowhere else the interest necessary to produce results.

When we review the life-work of SCHUMANN we find ourselves confronted by a problem. How did a man to whom every day brought new professional duties still find time to occupy himself so fully with scientific work? The solution is to be found in his creative impulse, in his gift of easy comprehension, in his powers of clear expression, and in his conscientious desire to crowd into his daily task the full force of all his intellectual activities.

The honors conferred upon SCHUMANN were not in proportion to his scientific importance or his distinguished gifts as a teacher. He was not made unhappy by this, but contented himself with the recognition of his colleagues, and found abundant compensation in the love and veneration everywhere paid him for his human qualities, his bright and cheerful nature, his courtesy, and his never-failing willingness to help.—*Translated by* J. PERKINS.

A CORRECTION.

IN THE June issue of the BOTANICAL GAZETTE, Mr. PLOWMAN publishes an article on "The celloidin method with hard tissues," stating that it has been "developed and perfected by Dr. E. C. JEFFREY," and that it "has been incompletely described at second and third hand elsewhere," in this connection calling attention to my book on *Methods in plant histology*. The collodion method was published in 1879, the celloidin method in 1882, and for nearly two decades both methods have been matters of text-book knowledge. Since I have used celloidin very little, except for woody tissues, I have made no effort to improve the method, but have simply followed more or less exactly and have described with slight variations the procedure in vogue in Professor EYCLESHYMER'S classes at the University of Chicago since 1893. Consequently, Mr. PLOWMAN is mistaken in assigning my account so high a rank as second hand, when in reality it is an accumulation so old that it cannot claim to be anything more than an ordinary text-book account, culled from older text-book accounts. Indeed, the use of hydrofluoric acid is the only essential addition by Mr. PLOWMAN to the long used celloidin methods.—CHARLES J. CHAMBERLAIN.

CURRENT LITERATURE.

BOOK REVIEWS.

Physiological plant anatomy.

THAT physiological anatomy is not one of those subjects that may be regarded as completed, so far as important new researches are concerned, is illustrated when one makes a comparison of the second and third editions of HABERLANDT's well-known work.[1] The first edition of this important work appeared in 1884, and since then there has been no excuse for the presentation of anatomy in a dead and formal manner. A second edition was issued in 1896,[2] and now in a still shorter time we are favored with a third edition. In this the pages have been increased from 550 to 616, and the figures from 235 to 264. While the general plan of the work resembles that of the second edition, there are many noteworthy additions in most of the chapters, and the latter part of the book has been rewritten, because the knowledge of these topics has been almost revolutionized, and in large part through the discoveries of the author himself.

The introductory chapters on plant cells and tissues, and embryonic tissues have suffered little change; a new section is added, dealing with the size of cells. In the chapter entitled "Das Hautsystem," there is a new subsection on secondary epidermal functions. Anthocyan receives a fuller treatment, while the recent studies of DAMM on perennial epidermis, and TITTMANN on the regeneration of wax rods are summarized. Little change in the treatment of the mechanical tissues is to be seen, except for the introduction of the experimental work of VÖCHTING, BALL, and WIEDERSHEIM. More is added regarding the absorption tissues. There is a new paragraph dealing with absorption in insectivorous plants, and SCHAAR's discovery of a cambium layer in the thallus of Rafflesia is fully described. The author clings to his former views regarding the functions of rhizoids and aerial roots, and fails to accept as conclusive the work of KAMERLING, PAUL, and NABOKICH. It is disappointing to see no essential change in the treatment of mycorhiza, a topic concerning which vastly more is known than in 1896. In the chapter entitled "Das Assimilationssystem," NORDHAUSEN's work on palisade cells is considered, but the excellent work of GRIFFON and others receives little or no mention. Latex tubes are still regarded as conductive vessels; ROTHERT's studies on the structure of the fibrous thickenings of conductive vessels give material for an interesting additional statement. The most notable

[1] HABERLANDT, G., Physiologische Pflanzenanatomie. Dritte, neubearbeitete und vermehrte Auflage. Imp. 8vo. pp. xvi+616. *fig. 264.* Leipzig: Wilhelm Engelmann. 1904.

[2] See review in BOT. GAZ. **23**:472. 1897.

additions to the chapter on storage tissues are a description of JÖNSSON's peculiar "mucilage cork," water storage cells derived from phellogen; and a note regarding FISCHER's work on inulin. Much new material is found in the chapter on aeration tissues: RACIBORSKI's breathing organs in early leaf stages; WESTERMAIER's remarkable but questionable lung-like organ on Sonneratia roots; BROWN and ESCOMBE's brilliant work on gas diffusion; KAMERLING on liverwort pores; PORSCH on adaptations for securing permanent closure in the stomata of submerged hydrophytes; and DEVAUX on lenticels. HABERLANDT disagrees in part with DEVAUX's results, and does not consider the paper as very important; he also rejects WIELER's results concerning aerenchyma. There is an excellent new figure of a lenticel, and another interesting new figure is that of the stoma of Nipa. Another chapter that is rich in new matter is that on "Die Sekretionsorgane und Exkretbehälter." The hydathode figure is much improved, and the rich recent literature on hydathodes is well summarized; little or no credit is given to the views of SPANJER and LEPESCHKIN, insofar as they are contrary to the views formerly expressed by the author. One of the notable additions here is the discovery of glands in Ruta which discharge to the exterior by means of slits that arise between external cells.

Far the most notable change of the new edition is to be found in the expansion of the old eleventh chapter, entitled "Apparate und Gewebe für besondere Leistungen." The material there presented is now considered in three chapters, entitled respectively "Das Bewegungssystem," "Die Sinnesorgane," "Einrichtungen für die Reizleitung." In the chapter on motor tissues there is a fuller discussion of the hygroscopic tissues. There is an entirely new section on cohesion mechanisms, embracing the contributions of KAMERLING, STEINBRINCK, and SCHRODT, regarding the movements that are due to the cohesive force of water in the cell lumina of fern sporangia and liverwort elaters. Much is also added in the section dealing with living motor tissues, embracing in particular the contributions of FITTING, SCHWENDENER, MÖBIUS, PANTANELLI, and HABERLANDT. The topic which has been most completely recast is that of the sense organs, and in this field HABERLANDT himself has been a pioneer and major contributor. This chapter for the most part may be regarded as a summary of the volume on this subject which has but recently come from the author's hand. After an introduction treating the general characteristics of sense organs in plants, there is a specific description of the tactile pits of Cucurbita and Drosera, the tactile papillae of various stamen filaments, and the tactile hairs of Centaurea, Biophytum, Mimosa, Aldrovandia, and Dionaea. Then follows an account of the sense organs for the perception of gravity and light stimuli; here there is a description of the statolith organs of plants, in which there is incorporated the chief results of NĚMEC, NOLL, JOST, DARWIN, and particularly those of the author. In the chapter on motor mechanisms, there is an entirely new section dealing with the intercellular and intracellular fibrillar structures, to which NĚMEC in particular has devoted so much attention. HABERLANDT

still holds to his former view concerning the motor mechanisms of Mimosa, in spite of the doubt cast upon his theory by the work of MACDOUGAL and FITTING.

The noteworthy changes that are to be found in this third edition make it necessary for all libraries. Many among us may not accept the teleological views that are to be found throughout the work, and it may occasion disappointment to find at several points, as stated above, that the author maintains his own unstable theories in the face of what will appeal to most botanists as conclusive proof against them. In particular, it is highly doubtful if we may longer believe in the condensing power of the aerial roots of orchids, conduction by the shortest route as explaining the elongation of palisade cells, the conductive function of latex tubes, the secretive rather than storage function of aleurone, or the hydrostatic propagation of stimuli in Mimosa.

The teleological views of the author are apparently not merely conveniences of expression, but purpose in plant structures appears to be regarded as an objective reality, which operates as a cause in the development of plant organs and tissues. As a consequence, it may not be surprising that the author is almost violent in his opposition to the contributions of such men as DEVAUX, SPANJER, and WIELER, and gives no place at all or at most inadequate consideration to the work of such men as GRIFFON, BERNARD, and FRIEDEL. The trend of modern investigation is certainly away from the idea that purpose is the directive factor in the evolution of structures, as well as from the idea that all structures must have a definite and advantageous function. However, the vast majority of structures are certainly useful, and the study of function in relation to structure gives life and vitality to what is otherwise a dead and profitless study to most students. And for this reason HABERLANDT'S work fills a place that is taken by no other work. For this reason, too, it is much to be hoped that there will soon be available a translation of this third edition.—H. C. COWLES.

Smoke and vegetation.

THERE have been a number of treatises dealing with the injurious effects of smoke on vegetation, but we are now favored with a monographic treatment of the subject by HASELHOFF and LINDAU.[3] There are first some general considerations on the origin of smoke, the characteristics and extent of its injuries to plants, the various causes of the formation of leaf spot, and the comparison of normal plant characteristics with injuries due to smoke. The body of the work deals with the injurious smokes and vapors in detail. Particular attention is paid to the effect of sulfurous and sulfuric acid vapors. Injurious effects are found to be associated chiefly with the foliage organs; little or no harm comes to the plant through vapors which may have been absorbed by the soil. Harmful effects are made evident through the formation of leaf spots, the death of leaves and young branches, the disorganization of chloroplasts, plasmolysis,

[3] HASELHOFF, E., and LINDAU, G., Die Beschädigung der Vegetation durch Rauch: Handbuch zur Erkennung und Beurteilung von Rauchschäden. Imp. 8vo. pp. viii+412. *figs.* 27. Berlin: Gebrüder Borntraeger. 1903. *M*10.

an increase of tannin deposits, and a reduction in the annual ring. An important point is that the stomata play no particular part in the absorption of the injurious vapors; the whole leaf appears to be involved in the process.

Plants vary widely in their power of resistance to noxious vapors; this might be anticipated in the case of different plant species, but it is strongly true as well among different individuals of the same species. Harmful effects are accelerated when there is an increase of light, heat or drouth, and as might be supposed therefrom, one of the first signs of injury is a drying out of the leaf, due to an impeded circulation of water. In a similar manner, though much less fully, the injurious influences of other smokes and vapors are discussed, *e. g.*, chlorin, hydrochloric acid, hydrofluoric acid, nitric acid, acetic acid, ammonia, hydrogen sulfid, bromin, tar, pyridin, phenol, fog, asphalt, illuminating gas, and dust. It will be seen from the list of subjects treated that the monograph considers all atmospheric elements apart from those which are commonly regarded as normal, whether or not they may be classed under the head of smokes or vapors. The book abounds in examples that have been taken from a wide field experience. For this and other reasons, the work will prove of great value to foresters, and to all who cultivate plants in the vicinity of cities or factories. And the botanist also will find here for the first time, perhaps, the injurious effects of smokes and vapors presented in such a way as to permit of ready reference.—H. C. COWLES.

Classification of flowering plants.[4]

MR. A. B. RENDLE has undertaken to present to the somewhat advanced student "a systematic account of the flowering plants," and the first volume, now before us, comprises the gymnosperms and monocotyledons. It may be said that the emphasis is laid upon classification, as the title would imply, rather than upon morphology. The essential morphology of the great groups is outlined briefly, but systematically and clearly, the modern point of view and terminology largely dominating, although it did not seem possible for the author to eliminate sexual terms entirely from the terminology of sporophytic structures.

The author regrets that "the means available did not allow of the preparation of large figures," for this feature of the book is out of all proportion to the value of the text. However, he has done remarkably well with the limitations that were set for him.

One of the most interesting chapters in the book is the first one, dealing with the evolution of plant classification. The subject is one which the author's experience has peculiarly fitted him to treat, and this chapter is one of the best compact presentations of it for the general student that we have seen.

Naturally the large usefulness of the book is in its full account of the plant groups, in which there is brought together a mass of information that will be of

[4] RENDLE, ALFRED BARTON, The classification of flowering plants. Vol. I. Gymnosperms and Monocotyledons. 8vo. pp. xiv + 403. Cambridge Biological Series. Cambridge: The University Press. 1904. $3.50.

great service to those who are not extreme specialists in the classification of seed-plants. The collated literature is supplemented by the large experience of the author, so that in a sense the presentation is distinctly a fresh one.

This book and others like it serve to emphasize the increasing differentiation between the specialists in morphology and those in classification. It is no longer possible for one man to do justice to both subjects in a single book. One or the other dominates in accordance with the larger interest of the author, and the other phase receives comparatively scant attention. In the book before us taxonomy is dominant, and only that amount of morphology is presented which is supposed to be of importance to a specialist in taxonomy. In other books morphology is dominant and taxonomy reduced to a bare outline. There is an additional complication in the case of seed-plants because of an old morphology that belongs to them. The old morphology has more dealings with taxonomy than it does with the new morphology, and will doubtless continue to be exploited chiefly by taxonomists. Anatomy has already become distinctly differentiated as a subject, and the morphologist of either kind has learned to touch it very lightly.—J. M. C.

MINOR NOTICES.

THE ISSUE of the twelfth edition of PRANTL'S *Lehrbuch der Botanik*, under the editorship of DR. PAX,[5] indicates that this book holds an assured place among German text-books. The present edition has been very slightly enlarged, though brought into line with modern work in many places. Improvements are also noticeable in many figures and some new ones are introduced.

Of its kind the book is excellent, but the kind no longer appeals to American botanists as a model. For it gives 122 pages to anatomy, 53 pages to physiology, and 279 to the dreary synopsis of plant families, which we suppose medical students and other victims of the required "allgemeine Botanik" are still forced to study—else it would hardly form so dominant a part of all German text-books. It might be well for our German friends to undertake a reform movement in botanical instruction.—C. R. B.

THE NINETEENTH PART of ENGLER'S *Das Pflanzenreich* consists of a presentation of Betulaceae by WINKLER.[6] The usual critical discussion of structure, geographic distribution, and systems of classification is followed by descriptions of 83 species recognized as representing 6 genera, all but 11 of the species belonging to Betula (37), Carpinus (18), and Alnus (17). In Carpinus 7 new species are described, and in Betula 3, but none of them belong to the American flora. Dr. BRITTON'S 4 new species of Betula recently described[7] are referred to in the *Addendum* as not examined. The conservative tendency of the work is indicated

[5] PAX, F., PRANTL'S Lehrbuch der Botanik. 12th ed. Imp. 8vo. pp. viii + 478. *figs.* 439. Leipzig: Wilhelm Engelmann. 1904.

[6] ENGLER, A., Das Pflanzenreich. Heft 19. Betulaceae von HUBERT WINKLER. pp. 149. Leipzig: Wilhelm Engelmann. 1904. *M* 7.60.

[7] Bull. Torr. Bot. Club **31**: 165. 1904.

not only by the few new species, but chiefly by the numerous varieties, especially in Alnus.—J. M. C.

To accompany his secondary school text-books, which imply a considerable amount of laboratory work in botany. Mr. J. Y. Bergen has prepared a *Notebook*,[8] in which he has arranged directions for experiments, chiefly physiological, with various useful suggestions to the student, intending thereby to promote neat and thorough reports of the work. Most teachers will prefer the loose-leaf notebook, which permits criticism and correction without permanently marring the record. The laboratory directions of course minimize dictation and copying, but the forms also curtail freedom and initiative which it is equally important to cultivate.—C. R. B.

Miss Perkins[9] has published the second fascicle of her contributions to the flora of the Philippine Islands. Numerous families are represented more or less extensively, the more important contributions dealing with Marantaceae, Leguminosae (9 n. spp.), the genus Canarium (Burseraceae) with 14 new species, Tiliaceae (9 n. spp.), Sterculiaceae (5 n. spp.), Asclepiadaceae (by R. Schlechter and O. Warburg) with 24 new species and a new genus (*Dorystephania*), and Gramineae (by C. Mez and R. Pilger) with 4 new species.—J. M. C.

The sixth fascicle of Roth's *Europäischen Laubmoose*[10] begins the Bryaceae, describing, with the help of ten plates, 21 species of Webera, 108 of Bryum, and 13 of other genera. The seventh fascicle completes the Bryaceae, Mniaceae, Meeseaceae, Aulacomniaceae, Bartramiaceae, Timmiaceae, and begins the Polytrichaceae. The ten plates, however, are almost wholly devoted to Bryaceae.—C. R. B.

Maiden,[11] in the fourth part of his revision of Eucalyptus, presents *E. incrassata* Labillardière and *E. fœcunda* Schauer, the description in each case being followed by discussion of synonymy, range, and affinities.—J. M. C.

NOTES FOR STUDENTS.

Porodko, as a result of his researches on the oxidases,[12] concludes that they probably do not take part in the process of respiration. He also contributes some facts to the technique of the guaiac reaction.—C. R. B.

[8] Bergen, J. Y., Notebook to accompany Bergen's text-books of botany or for general use in botanical laboratories of secondary schools. 4to. pp. 144. Boston: Ginn & Co. 1904. 75 cents.

[9] Perkins, J., Fragmenta florae Philippinae. Fasciculus II. pp. 67–152. *pls. 1–3.* Leipzig: Gebrüder Borntraeger. 1904. *M* 5.

[10] Roth, Georg, Die europäischen Laubmoose. 2 Band. 6 Lieferung. Imp. 8vo. pp. 1–128. *pls. 1–10.* 7 Lieferung. pp. 129–256. *pls. 11–20.* Leipzig: Wilhelm Engelman. 1904. Each *M* 4. (Parts not sold singly.)

[11] Maiden, J. H., A critical revision of the genus Eucalyptus. Part IV. pp. 93–124. *pls. 13–24.* Government of New South Wales: 1904.

[12] Porodko, T., Zur Kenntniss der pflanzlichen Oxidases. Beihefte Bot. Cent. **16**: 1–10. 1904.

BERNARD adds his name[13] to the increasing list of those who are unable to obtain evidence of photosynthesis outside the organism. Using various methods he "obtained no positive appreciable results."—C. R. B.

LOCK[14] has made some interesting observations upon a variety of *Turnera ulmifolia* that has become naturalized in Ceylon. The flowers are distinctly heterostylic and apparently absolutely self-sterile, and the pollinating insects are bees, notably *Apis indica*. The seeds are most commonly dispersed by the aid of harvesting ants.—J. M. C.

A NOTE in the July number regarding the experiments of KOERNICKE on radium emanations should have included reference to the experiments of DIXON, who found seedlings retarded in growth without serious injury. Experiments on cultures of 48 species of bacteria by DIXON and WIGHAM[15] showed inhibition of development, confirming the results of other observers.—C. R. B.

FRIES[16] has published an interesting article on ornithophily in the South American flora, arriving at the conclusion that there is no distinct difference between ornithophilous and entomophilous flowers, and that the same species may be pollinated as well by insects as by humming birds in one place, while in another locality either of these agents may be acting.—P. OLSSON-SEFFER.

INTERCELLULAR protoplasm in the cotyledon of *Lupinus albus* is reported by KNY[17]. This protoplasm does not seem to differ from that contained within the cells, except that it contains no nuclei, starch grains, or plastids. Ripe seeds were used in the investigations. The behavior of the intercellular protoplasm during the germination of the seed will be described in a future paper. —CHARLES J. CHAMBERLAIN.

IN A PAPER on the flora of the mountains of northern Finland, BORG[18] gives the results of his studies of the plant distribution within two of the zones occurring in these mountains, none of them higher than 1200^{m}. The paper discusses in detail the composition of the mountian flora and the origin of its components.

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[13] BERNARD, CH., Sur l'assimilation chlorophyllienne. Beihefte Bot. Cent. **16**: 36–52. 1904.

[14] LOCK, R. H., Ecological notes on *Turnera ulmifolia* L., var. *elegans* Urban. Annals Roy. Bot. Gard. Peradeniya **2**: 107–119. 1904.

[15] DIXON, H. H., and WIGHAM, J. T., Preliminary note on the action of the radiations from radium bromide on some organisms. Sci. Proc. Roy. Dublin Soc. N. S. **10**^{2}: 178–192. *pls. 16–18*. 1904.

[16] FRIES, R. E., Beiträge zur Kenntniss der Ornithophilie in der südamerikanischen Flora Arkiv for Botanik **1**: 389–440. 1904.

[17] KNY, L., Studien über intercellulares Protaplasma. I. Ber. Deutsch. Bot. Gesells. **22**: 29–35. 1904.

[18] BORG, VÄINÖ, Beiträge zur Kenntniss der Flora und Vegetation der finnischen Fjelde (alpinen und subalpinen Gebirge). I. Acta Soc. pro Fauna et Flora Fennica **25**: no. 7. pp. 170.

The promised second part dealing with the vegetation will probably be of greater interest.—P. OLSSON-SEFFER.

WIESNER describes[19] casting of leaves in summer due to deficient light and to consequent interference with photosynthesis, which is distinct from a similar effect of drouth and heat and not continuous with the autumn defoliation. The loss amounts to 8–30 per cent. of the foliage in sensitive trees. It begins, in those trees which complete their leaf formation in spring, when the midday sun has reached the same elevation at which foliation was completed, whereas it is almost imperceptible in trees whose foliation extends into the summer.—C. R. B.

BEARD[20] has discussed "the track of heredity" in plants and animals, chiefly the latter. A luminous statement in reference to plants is as follows: "In the embryo-sac of Pinus, which is the gametophyte, there are only four germ-cells. In the corresponding structure in flowering plants there are perhaps three, or at most six; while, as is well known, the male gametophyte of a flowering plant is represented by one or two vegetative cells and one or two germ-cells." This may be clear to a zoologist, but its interpretation is beyond the powers of the plant morphologist.—J. M. C.

BLAKESLEE[21] has made preliminary announcement of his results in a study of the methods of reproduction in Mucorineae. It seems that zygospore production in this group "is conditioned by the inherent nature of the individual species and only secondarily or not at all by external factors." Two methods of zygospore formation are recognized, and upon this basis Mucorineae may be divided into two groups designated as "homothallic" and "heterothallic," the terms corresponding to "monoecious" and "dioecious" among higher forms. The general conclusions are that the formation of zygospores is a sexual process, that the mycelium of a homothallic species is bisexual, that the mycelium of a heterothallic species is unisexual, and that among the heterothallic species certain ones have a distinct differentiation of sex. It is interesting to note that in conjugation the swollen portions ("progametes") from which the gametes are cut off do not "grow toward each other," as commonly stated, but arise as a result of the stimulus of contact between hyphae, and are from the outset adherent.—J. M. C.

MASTERS[22] has published a synopsis of the genus Pinus, the purpose of which he states is "to add to our knowledge of the species and to facilitate their deter-

[19] WIESNER, J., Über Laubfall infolge Sinkens des absoluten Lichtgenusses (Sommerlaubfall). Ber. Deutsch. Bot. Gesells. **22**:64–72. 1904.

[20] BEARD, J., The track of heredity in plants and animals. Trans. and Proc. Bot. Soc. Edinburg **22**:126–155. *figs. 3.* 1902.

[21] BLAKESLEE, ALBERT FRANCIS, Zygospore formation a sexual process. Science N. S. **19**:864–866. 1904.

[22] MASTERS, MAXWELL T., A general view of the genus Pinus. Jour. Linn. Soc. Bot. **35**:560–659. *pls. 20–23.* 1904.

mination." The genus is limited, as is usual now, to those abietinous forms in which both shoots and leaves are dimorphic. A somewhat full discussion of the value of the histological characters often used in classification reaches the conclusion that they have no greater intrinsic value than any other characters, being useful but not infallible guides, likely to vary more than some other characters. The two great divisions proposed are TENUISQUAMAE (with relatively thin cone-scales) and CRASSISQUAMAE (with cone-scales notably thickened toward the apex). Under the former are the sections *Strobus* (10 spp.) and *Cembra* (3 spp.); under the latter the sections *Integrifoliae* (8 spp.), *Serratifoliae* (4 spp.), *Indicae* (3 spp.), *Ponderosae* (12 spp.), *Filifoliae* (7 spp.), *Cubenses* (5 spp.), *Sylvestres* (10 spp.), and *Pinaster* (11 spp.). A useful feature of the contribution is a chronological list of specific names, extending from 1753 to 1903. The author's long study of the genus makes this contribution unusually rich in facts and suggestions.—J. M. C.

TRANSEAU[23] has made a preliminary announcement of certain results in connection with the investigation of the causes of xerophily in bog plants. Using *Rumex Acetosella*, great modification in the appearance and structure of the leaves was produced by varying the conditions; for example, growing in moist conditions and in dry sand. Also, the marked xerophilous characters induced by growth in the latter substratum were also obtained by growth in an undrained wet sphagnum substratum of low temperature. Further, under these conditions the drops of oil or resin, characteristic of bog xerophytes, were formed in the epidermis and in the cells adjacent to the bundles. He concludes that these modifications in the case of the bog habitat are a response to the unfavorable conditions for absorption by the roots, due to low temperature and lack of aeration. It is also suggested that the development of palisade tissue in response to strong light is correlated with drouth rather than with light, resulting from increased transpiration. "The elongated palisade cells, therefore, are an adaptation for the ready transfer of food materials in the leaf tissues, under the stress of a reduced water supply."—J. M. C.

HABERLANDT in reexamining the perceptive mechanism of heliotropic leaves finds three types:[24] (1) those in which the lamina alone is sensitive; *e. g.*, *Begonia discolor* and probably shade plants in general; (2) those whose lamina and petiole are perceptive; *e. g.*, *Tropaeolum* spp., *Malva verticillata* (*fide* VÖCHTING), and probably climbing and twining plants; (3) those whose petioles or motor organs are sensitive; *e. g.*, Phaseolus. He suggests that in euphotometric foliage leaves the cells of the upper epidermis constitute a sensory epithelium for the perception of light. Sometimes all cells share alike in this function, but in some plants certain cells are specialized, forming a more localized sense organ. In either

[23] TRANSEAU, E. N., On the development of palisade tissue and resinous deposits in leaves. Science N. S. **19**:866–867. 1904.

[24] HABERLANDT, G., Die Perception des Lichtreizes durch das Laubblatt. Ber. Deutsch. Bot. Gesells. **22**:105–119. *pl. 8.* 1904.

case the essential feature is a sensitive layer of protoplasm and an apparatus which concentrates the light upon this plasma, of which certain regions are either more or less strongly illuminated when the organ is out of its normal relation to the incident light. Two types are distinguished: those in which the outer face of the epidermal cell is convex, and those in which the inner wall is convex toward the mesophyll or is the frustum of a cone. The hypothesis is not supported by any experimental evidence, but is constructed merely from anatomical observations and *a priori* reasoning. (See also p. 157.)—C. R. B.

WAGER[25] has studied the nucleolus during nuclear division in the root of Phaseolus. After a summary of the extensive literature and a description of methods, the subject is presented under the following heads: the resting nucleus, structure of the nucleolus, changes in the nucleolus during the prophase, and reconstitution of the daughter-nuclei. The main conclusions are that the nucleolus simply forms a part of the nuclear network, in which chromatin or chromatin-substance may be stored, and therefore is not an independent organ of the nucleus; that it is concerned in the formation of the chromosomes, and possibly also in the production of the spindle, and that a portion of it may in some cases be extruded into the cytoplasm and there disappear; that in the reconstruction of the daughter-nuclei the chromosomes unite together in a more or less irregular mass or thick thread, out of which is evolved the nucleolus and nuclear network, the major part of the chromatin passing ultimately into the nucleolus, except in cases where division again immediately takes place. Attention is called to the fact that if these conclusions are correct, the part played by the chromosomes in heredity will need revision, and that the nucleolus as well as the chromosomes will have to be taken into account.—J. M. C.

SALMON[26] has published the results of experiments with the so-called "biologic forms" of the Erysiphaceae, that is, races of individuals morphologically identical, but differing physiologically in possessing distinctive and sharply defined powers of infection. This specialization of parasitism has been found to be associated with both conidia and ascospores. The present experiments show that the restriction in power of infection characteristic of "biologic forms" breaks down if the vitality of the leaf is interfered with in certain ways, as by wounding. It was found also that conidia produced on a wounded leaf that was normally immune to such attack would infect uninjured leaves of the plant in question; by means of this "bridge" passing from one host plant to another. Injuries to leaves in nature, resulting in such bridging, were observed to be made by the "green fly" (Aphis). Therefore, in the evolution of "biologic forms" two sets of factors are at work: one, called "specializing factors," tending to specialize parasitism and deriving from a single morphological species a number

[25] WAGER, HAROLD, The nucleolus and nuclear division in the root apex of Phaseolus. Annals of Botany **18**: 29–55. *pl.* 5. 1904.

[26] SALMON, ERNEST S., Cultural experiments with "biologic forms" of the Erysiphaceae. Phil. Trans. Roy. Soc. London B. **197**: 107–122. 1904.

of "biologic forms;" the other, called "generalizing factors," bridging these differences and causing "the separate streams of evolving 'biologic forms' to flow into each other." It is thought that these facts may explain the sudden appearance of a parasitic disease on plants which had hitherto proved immune.—J. M. C.

DUVEL[27] has been investigating, since 1899, the causes affecting the vitality of seeds, with special reference to the conditions under which they are stored commercially. The general method pursued has been to store seed experimentally under all sorts of conditions, and afterward to ascertain the exact percentage of germination. The first factors determining the vitality of a seed are maturity, weather conditions at the time of harvesting (damp weather lowering the vitality), and methods of harvesting and curing (especially avoiding excessive heating). The life-period of a seed that has met these favorable conditions depends on environment, but the average life varies greatly in different families, genera, or even species. There is no relation between the longevity of plants and the viable period of the seeds they produce. With proper precautions, the life of seeds may be greatly prolonged beyond the present record, and in commercial handling moisture is the chief factor in shortening it. It seems that seeds can endure any degree of drying without injury, and that such a reduction in the water content is necessary if vitality is to be preserved for a long period of years. It is said that "respiration" is not necessary to the life of a seed, and that the evidence goes to show that it "is not dependent on the preservation of the particular ferment involved or on the zymogenic substance giving rise to the enzyme." "The one important factor governing the longevity of good seed is *dryness*." —J. M. C.

S. M. COULTER[28] has published a preliminary account of his investigation of swamps. The paper is intended to collect and group together the facts concerning the swamp areas investigated as a basis for a future study of the problems involved. The data have been obtained from field studies extending through three years and including swamps of six types: (1) a drained swamp along Crooked River, in the northern part of the lower peninsula of Michigan; (2) an undrained tamarack and black spruce swamp on North Manitou Island, Lake Michigan; (3) a slowly drained arbor vitae swamp on the same island; (4) the small, swampy lakes south of Chicago; (5) Horseshoe Lake, an old "ox-bow" cut off from the Mississippi River in southwestern Illinois; and (6) a cypress and tupelo gum swamp in northeastern Arkansas. The discussion of these types consists of a description of the present topographical condition of each area, together with a summary of the principal plant forms that characterize it. In short, the paper is a brief comparison of certain widely separated swamp areas

[27] DUVEL, J. W. T., The vitality and germination of seeds, pp. 96. Bull. 58. Bur. Pl. Industry, U. S. Dept. Agric. May 28, 1904.

[28] COULTER, SAMUEL MONDS, An ecological comparison of some typical swamp areas. Rep. Mo. Bot. Gard. **15**:39–71. *pls. 24.* 1904.

of different types expressed in terms of physiography and taxonomy, the history and dynamics of each being reserved for later treatment. A somewhat detailed account is given of *Nyssa uniflora*, special attention being called to the very much enlarged base, an enlargement which does not become conspicuous where the water supply is scanty; and of *Taxodium distichum* with its enlarged base and "knees," neither of which phenomena appears in connection with dry soil. The half-tone reproductions of good photographs are excellent and form a substantial addition to the data presented by the paper.—J. M. C.

REGENERATION.—WINKLER'S [29] experiments on Torenia show that detached leaves of this plant may produce buds from any part of the upper epidermis. The shoots proceeding from these buds bloom at once, independent of the age of the parent plant and of the place on the plant from which the leaf is taken. The term "regeneration" should be confined to cases such as this, where fully differentiated cells resume the embryonal state.—SIMON[30] has studied the exact region of regeneration in root tips, and determined by microscopic observation and by experiment that the pericambium is essential. He distinguishes direct regeneration or replacement of the tip from partial regeneration, where the pericambium grows out from the cut surface in the form of a ring and the new tissue eventually spreads over the whole cut surface. The latter variety of regeneration occurs when more than about 0.75^{mm} of the root tip is cut off; if $1\text{-}3^{mm}$ is cut off, no regeneration takes place, but lateral roots replace the primary root. Three periods of regeneration are distinguished: (1) reaction, time occupying about one day, (2) introductory phase, consisting in pericambial division, (3) definite formation of the new tissue.—VÖCHTING[31] calls attention to the marked lack of plasticity in *Araucaria excelsa*. The bilateral branches of the first order when used as cuttings produce a plant which retains the bilateral habit; branches of the second order root slowly and grow in length without branching; only the tip of the main axis gives a plant of the regular radial habit. As to the nature of regeneration in general, the writer holds that the capacity to regenerate, though not always of use either to the individual plant or to the species, is as characteristic a phenomenon as is growth.—M. A. CHRYSLER.

THE MODE in which light affects perceptive organs is awakening interest. In his paper summarized on p. 154, HABERLANDT suggests that perhaps light is perceived by reason of the difference in pressure between illuminated and dark areas. The same suggestion is made by JOST,[32] but neither mentions RADL,[33]

[29] WINKLER, H., Ueber regenerative Sprossbildung auf den Blättern von *Torenia asiatica*. Ber. Deutsch. Bot. Gesells. **21**:96–107. 1903.

[30] SIMON, S., Untersuchungen über die Regeneration der Wirzelspitze. Jahrb. Wiss. Bot. **40**:103–143. 1904.

[31] VÖCHTING, H., Ueber die Regeneration der *Araucaria excelsa*. Jahrb. Wiss. Bot. **40**:144–155. 1904.

[32] Vorlesungen über Pflanzenphysiologie 586. Jena. 1904.

[33] Unters. über den Phototropismus der Tiere. Leipzig. 1903.

who seems to have ascribed phototropism in animals to the same fundamental cause, though he thinks of the reactive pull rather than pressure. Utilizing the figures calculated by MAXWELL (1873) and recently determined experimentally by NICHOLS and HULL,[34] the pressure on a cell .01^{mm} square in full sunlight would scarcely amount to 7×10^{-11} milligram! To believe that a plant cell could discriminate between 0 and .000,000,000,07^{mg} pressure (*i. e.*, of darkness and of full sunlight) makes a severe test of one's credulity; but when one remembers that some plants discriminate between darkness and the light of one candle at a distance of 50^{m}, and that the phototropic optimum of Vicia lies at 3 candles, the reason simply balks at any possibility of the perception of such differences of pressure.

RADL, who has enunciated this idea regarding phototropism in animals,[35] and who endeavored unsuccessfully to test it experimentally with them, has turned to seedlings for confirmation. In a late paper[35] he endeavors to minimize the objection grounded on the minuteness of the energy involved (which seems absolutely conclusive against the hypothesis), and describes briefly a series of experiments in which he hung seedlings horizontally in a moist chamber by a cocoon filament, so that they were poised at right angles to light admitted through a slit, while control seedlings were fastened in a like position. He then observed whether or not the free ones were caused to rotate, directing their apices toward the light. Arguing that according to the extent of such rotation any curvature they might also attain would be less than in the fixed controls, he interprets his 51 results as giving 39 cases in support of his hypothesis and 12 against it. The sources of error both in experimentation and interpretation are so numerous and the results are so inharmonious as to leave the matter still *in statu quo*. The author recognizes the inconclusiveness of his results, but thinks them suggestive. —C. R. B.

MUCH HAS BEEN written regarding the mycoplasm theory put forth by Dr. JAKOB ERIKSSON, of Sweden, to account for outbreaks of wheat rust when external infection from aecidiospores or uredospores is presumably impossible. In a recent article[36] ERIKSSON gave a concise statement of his position, in order to set right his critics and opponents in regard to the fundamental conception of his theory.

He has now laid the botanical public under a debt of gratitude by publishing a first instalment of his histological studies which form the solid basis of his theory, and by illustrating them with excellent colored plates.[37] Beginning is

[34] Physical Review **17**: 101. 1903.

[35] RADL, E., Ueber die Anziehung der Organismen durch das Licht. Flora **93**: 167–178. 1904.

[36] Archiv für Botanik **1**:139–146.

[37] ERIKSSON, J. and TISCHLER, G., Ueber das vegetative Leben der Getreiderostpilze. I. *Puccinia glumarum* in der heranwachsenden Weizenpflanze. Kongl. Svensk. Vet. Akad. Handl. **37**:—. [no. 6. pp. 19.] *pls.* 3. 1904.

made with a study of the vegetative life of the yellow rust of wheat, *Puccinia glumarum*, a species not known outside of Europe, and for which no aecidium has been discovered.

After an introduction, in which some of the difficulties in explaining infection and distribution are indicated that have arisen since DEBARY'S time, the materials and methods for the investigation are described. Modern histological methods were employed. Best results were obtained with FLEMMING'S fixative, and FLEMMING'S safranin-gentian-violet-orange stain. From October 6 to October 27, 1902, and April 28 to June 18, 1903, no trace of mycelium was found in any of the microtome sections, but in many cells a protoplasmic mixture occurred, which the author has called mycoplasm, because he believes it to be a mixture of the common protoplasm of the cell and the protoplasm of the rust derived from the germinating seed. The mycoplasm does not at first interfere with the chlorophyll grains or nucleus, but these disappear after a time, and the cell wall is filled with a uniform granular mass.

As the wheat plant continues to grow there appears in the intercellular spaces similar granular masses, which soon become filamentous, although possessing no walls or nuclei. As development proceeds, however, well-defined nuclei appear. This naked intercellular stage, whether with or without nuclei, the author designates as protomycelium. This stage is soon followed by the appearance of bounding walls to the filaments, and after a time cross walls, when the ordinary vegetative state of the fungus is attained.

Although the author has not been able to trace the transition between the form within the cells, mycoplasm, and the form between the cells, protomycelium, he is confident that the first gives rise to the second.

Whether or not this clearly stated and well-illustrated article carries conviction to the reader, it nevertheless is a satisfaction to be able so clearly to apprehend the grounds upon which the mycoplasm theory is based.

In a recent article KLEBAHN[38] has supplemented one of his earlier articles[39] with details bearing directly upon the mycoplasm theory. He gives figures in the text showing essentially the same phenomena which ERIKSSON has so strikingly set forth with colored plates. The lack of perfect agreement between the two authors can well be ascribed to manipulation of the preparations. But the conclusions drawn from these studies by KLEBAHN are wholly different from those reached by ERIKSSON, and favor a theory of abnormal and accidental conditions rather than a theory of mycoplasma.—J. C. ARTHUR.

[38] KLEBAHN, H., Einige Bemerkungen über das Mycel des Gelbrostes und über neueste Phase der Mykoplasma Hypothese. Ber. Deutsch. Bot. Gesells. **22**:255–261. 1904.

[39] Zeits. Pfl. Krank. **10**:88 et seq. 1900.

NEWS.

DR. CHARLES J. CHAMBERLAIN has been elected a member of the German Botanical Society.

THE SIXTH session of the University of Montana Biological Station is in progress at Flathead Lake, Montana.

PROFESSOR DR. GY. DE ISTVÁNFFI has been awarded the THORE prize by the Institut de France for his "Études sur le rot livide de la vigne."

THE BUREAU of Government Laboratories of the Philippine Islands has undertaken the establishment of a botanical garden at Lamao, across the bay from Manila.

EMMANUEL DRAKE DEL CASTILLO died at his Château de Saint-Cyran on May 14, 1904, at the age of 48. He was formerly president of the Botanical Society of France, and a well-known systematist.

ARKIV FOR BOTANIK is the title of a new botanical publication, issued by the Royal Swedish Academy of Sciences in Stockholm instead of the Academy's previous "Oefversigt" and "Bihang till Handlingar," which have been discontinued.

PROFESSOR CLARA E. CUMMINGS, of Wellesley College, has been granted a sabbatical year, which will be spent in resting and studying the tropical flora. Associate Professor FERGUSON will have charge of the department for the year.—*Science.*

DR. WLADISLAW ROTHERT, professor of botany in the University of Odessa, is making a brief tour of the northeastern United States, in connection with a visit to the Louisiana Purchase Exposition. He has had time to see only the botanical establishments at Washington, St. Louis, Chicago, New York, and Boston.

PROFESSOR VOLNEY M. SPALDING has resigned the headship of the Department of Botany at the University of Michigan. He will continue his work at the Desert Laboratory of the Carnegie Institution at Tucson. All correspondence pertaining to the department should be addressed to Professor F. C. NEWCOMBE.

THE CLARENDON PRESS announces that it is preparing to publish translations of SOLEREDER'S *Systematic anatomy of the Dicotyledones* by L. A. BOODLE and F. E. FRITSCH, revised by D. H. SCOTT; EICHLER'S *Flower diagrams*, by H. E. F. GARNSEY, revised by I. B. BALFOUR; KNUTH'S *Pollination of flowers* by GREGG WILSON and AINSWORTH DAVIES; and WARMING'S *Plant geography*. The translation of the last will be made from a new edition which the author is preparing. It is hoped that the translation will appear simultaneously with the new edition. The name of the translator is not given.